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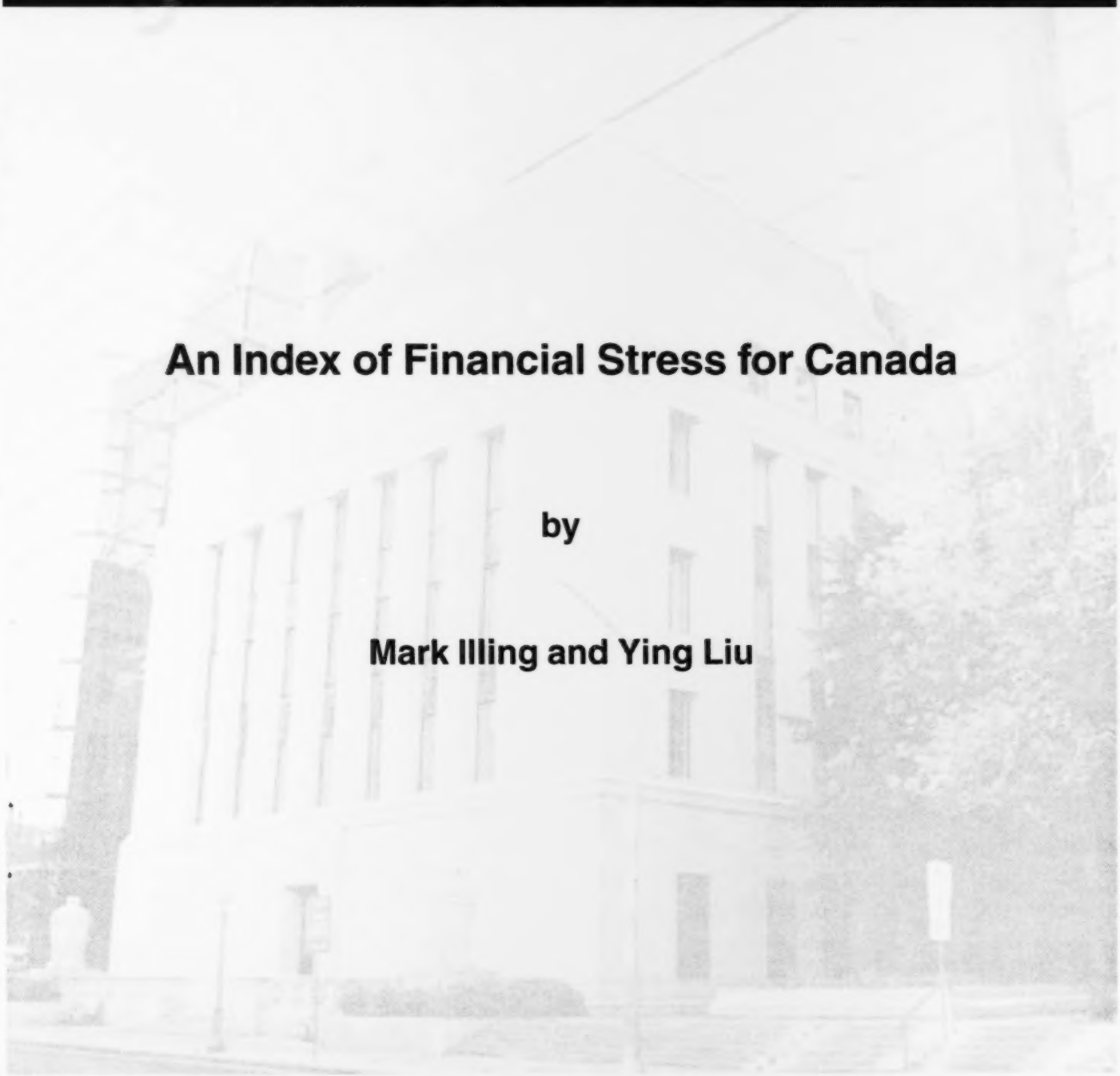
# An Index of Financial Stress for Canada

by

**Mark Illing and Ying Liu**



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The views expressed in this paper are those of the authors.
No responsibility for them should be attributed to the Bank of Canada.

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## Abstract

The authors develop an index of financial stress for the Canadian financial system. Stress is defined as the force exerted on economic agents by uncertainty and changing expectations of loss in financial markets and institutions. It is a continuous variable with a spectrum of values, where extreme values are called financial crises. Information about financial stress is extracted from a wide array of financial variables using several techniques, including factor analysis, econometric benchmarking, and generalized autoregressive conditional heteroscedasticity (GARCH) modelling. An internal Bank of Canada survey is used to condition the choice of variables and to evaluate their ability to reflect the responses to the survey regarding highly stressful financial events. The authors show that alternative measures of financial crises suggested by the literature do not accurately reflect the results of the survey, while several measures developed in this paper do reflect them.

*JEL classification: G10, E5*
*Bank classification: Financial institutions; Financial markets*

## Résumé

Les auteurs élaborent un indice de stress financier pour le système financier canadien. Le stress est défini comme la tension ressentie par les agents économiques du fait de l'incertitude et des modifications des attentes de pertes dans les institutions et les marchés financiers. Il se présente comme un continuum prenant toute une série de valeurs et dont les extrêmes sont appelés crises financières. L'information au sujet du stress financier est extraite d'un large éventail de variables financières à l'aide de plusieurs méthodes, dont l'analyse factorielle, l'étalonnage économétrique et le recours à des modèles autorégressifs conditionnellement hétéroscédastiques généralisés (GARCH). Le choix des variables examinées s'inspire d'une enquête interne que la Banque du Canada a menée pour déterminer quels événements ont occasionné le plus de stress au système financier canadien. Les auteurs évaluent ensuite la capacité de ces variables à refléter les réponses données à l'enquête. Ils montrent que les divers indices proposés dans la littérature ne sont pas satisfaisants, alors que plusieurs de leurs propres mesures donnent de bons résultats.

*Classification JEL : G10, E5*
*Classification de la Banque : Institutions financières; Marchés financiers*

# 1. Introduction

This paper formalizes the concept of financial stress, proposes competing ordinal measures of stress, and evaluates which measure conforms most closely with responses to a Bank of Canada survey regarding highly stressful financial events. Financial stress is defined as the force exerted on economic agents by uncertainty and changing expectations of loss in financial markets and institutions. Financial stress is a continuum, measured in this paper with an index called the Financial Stress Index (FSI), where extreme values are called financial crises.

The literature on financial crises devotes little attention to actually measuring the contemporaneous severity of these crises. In fact, crises are most often measured by simple binary variables. Moreover, crises are usually treated as banking and/or currency phenomena, rather than system-wide events. The literature on financial crises in developing countries is quite extensive, and numerous models using early-warning indicators (EWIs) have been created.[1] However, these models have not been successfully applied to highly developed countries, owing to the rarity of crises in large mature markets.

The FSI addresses the weakness inherent in models that use EWIs by improving the reference variable. In particular, the FSI is continuous, of high frequency (daily), and covers the equity markets, bond markets, foreign exchange markets, and the banking sector. Therefore, it is far better suited to analyzing financial stability in highly developed countries with numerous systemically important financial markets and institutions.

The FSI also provides a timely snapshot of contemporaneous stress in the Canadian financial system. Until now, the lack of a comprehensive measure has made it difficult to gauge the severity of financial events as they transpire.

To develop our FSI, we conducted an internal Bank of Canada survey to determine which events over the past 25 years were most stressful for Canada's financial system. With the survey results in hand, variables are then selected according to a literature review and combined into indexes. The variables are also chosen for their timeliness, forward-looking information, systemic relevance, and ability to reflect agents' behaviour. The constructed indexes are evaluated based on their ability to match the results of the survey. Therefore, our FSI more directly reflects the Canadian experience than measures suggested by the literature.

---

1. Appendix A provides a brief review of the literature on EWIs.

Section 2 clarifies the concept of financial stress. Section 3 reviews the measures commonly used in the literature to define extreme stress events (i.e., crises). Section 4 briefly describes the results of the survey on financial stress. Section 5 describes the variables chosen, conditioned on the literature and information gleaned from the survey. Section 6 describes how to best combine these variables into a single index. Section 7 compares the various versions of the FSI and the measures suggested in the literature with the survey responses. Section 8 concludes and suggests avenues for future research.

## 2. Conceptualizing Financial Stress

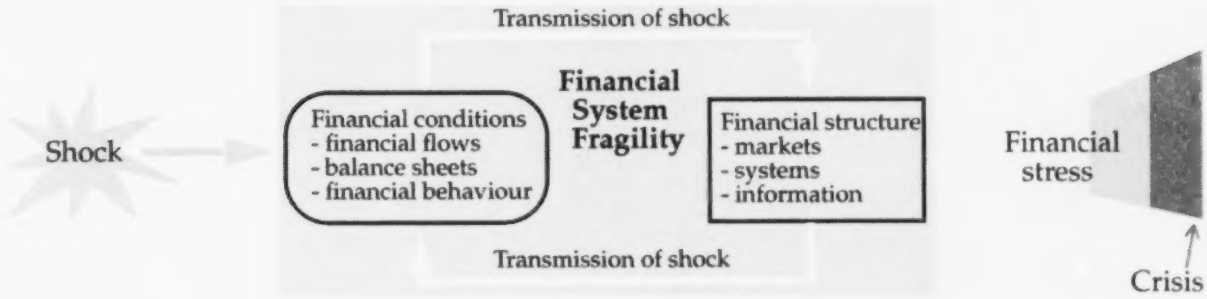
If financial stress is systemic, economic behaviour can be altered sufficiently to have adverse effects on the real economy.[2] Therefore, financial stress is a continuous variable with a spectrum of values, where extreme values are called a crisis. Stress increases with expected financial loss, with risk (a widening in the distribution of probable loss), or with uncertainty (lower confidence about the shape of the distribution of probable loss).

This paper attempts to derive an ordinal estimate of macroeconomic financial stress in the form of an index. A variety of measures of probable loss, risk, and uncertainty are compiled from the banking, foreign exchange, debt, and equity markets (the four most important credit channels in Canada). Stress in the household sector and the non-financial business sector is implicitly reflected in the behaviour of agents in these four markets.

Stress is the product of a vulnerable structure and some exogenous shock. Financial fragility describes weaknesses in financial conditions and/or in the structure of the financial system. A shock is more likely to result in stress (in the extreme, a crisis) when financial conditions are weak; for example, when cash flows diminish rapidly, balance sheets are highly leveraged, or lenders become more risk-averse. Shocks may also propagate through weakness in the structure of the financial system, as when there are market coordination failures, or computer systems become overloaded, or the flow of information is highly asymmetric. The size of the shock and the interaction of financial-system fragilities determine the level of stress (Diagram 1).

2. This conforms to the Group of Ten (2001) definition of financial crisis as "an event that will trigger a loss in economic value or confidence in a substantial portion of the financial system that is serious enough to . . . have significant adverse effects on the real economy."

**Diagram 1: Schematic of Financial Stress**




# 3. The Literature on Identifying Crises and Measuring Financial Stress

Many empirical studies of financial stability focus on selecting EWIs of crises, but most use simple definitions of the crises themselves. Typically, crises are identified with binary variables based on extreme values of one or two underlying financial variables. Crises in different markets are usually considered separately.

This section describes the variables used in the literature to define a crisis. Table 1 details these variables and gives some of our own suggestions. Section 5 describes our choice of variables based on this review.

## 3.1 Banking crises/stress

Because of the lack of suitable data and institutional differences across countries, it can be challenging to define a banking crisis; the analysis relies mostly on qualitative information. Many studies avoid explicitly defining banking crises and rely on judgment. For example, Kaminsky and Reinhart (1996, 1999) and Logan (2000) define banking crises on an ad hoc basis as a combination of country-specific events. But a few studies have addressed the issue directly. Examples include Bordo (1985, 1986), who defines a banking crisis as a situation where actual or incipient bank runs or failures lead banks to suspend the internal convertibility of their liabilities (i.e. they are unable to meet their obligations). Caprio and Kilingebiel (1996) define a systemic banking crisis as an instance in which bank failures or suspensions lead to the exhaustion of much or all bank capital. Based on the extent of the problem, they identify crises of various degrees of intensity in 69 countries.

More recent papers combine this qualitative approach with a limited number of quantitative criteria. For example, Demirgüç-Kunt and Detragiache (1998) define a banking crisis as a situation where at least one of the following conditions holds: (i) the ratio of non-performing assets to total assets is greater than 10 per cent,[3] (ii) the cost of the rescue operation is at least 2 per cent of GDP, (iii) banking problems result in the large-scale nationalization of banks, and (iv) extensive bank runs lead to emergency measures.

A more quantitative method of identifying a banking crisis involves the use of aggregate balance-sheet data. The literature frequently uses three measures to identify bank balance-sheet problems: (i) the stock of non-performing loans as a percentage of total assets (Corsetti, Pesenti, and Roubini 1998; González-Hermosillo 1999), (ii) bank deposits as a percentage of GDP (Hardy and Pazarbasioglu 1998), and (iii) lending as a percentage of GDP (Hardy and Pazarbasioglu 1998; Sachs, Tornell, and Velasco 1996).

The above-noted studies almost exclusively address banking sector problems in developing countries. Vila (2000), however, proposes two measures of banking stress for the United States: the first based on falling bank equity prices, and the second on unsustainable aggregate deposit growth.[4]

## 3.2 Foreign exchange crises/stress

Foreign exchange (currency) crises are usually defined as significant devaluations, losses in reserves, and/or defensive interest rate increases.

Frankel and Rose (1996) define a currency crisis as a nominal depreciation of at least 25 per cent that exceeds the previous year's change by a margin of at least 10 percentage points. To take into account the possibility of government intervention in case of a speculative attack, Kaminsky, Lizondo, and Reinhart (1998) and Caramazza, Ricci, and Salgado (2000) take a weighted average of exchange rate changes and reserve losses. They then define crisis thresholds in terms of standard deviations from the mean. Corsetti, Pesenti, and Roubini (1998) use a similar measure, but employ multiple thresholds to achieve a graded index. Eichengreen, Rose, and Wyplosz

3. The ratio of banking sector non-performing loans to total loans (in this paper, loans and assets are considered to be synonymous) peaked at 2.5 per cent in Canada in 1993, 4 per cent in the United States during the Savings and Loans crisis, 10 per cent during the early-1990s Scandinavian banking crisis, and were estimated by Japanese authorities to be 8 per cent by the end of 1999. During the Asian crisis, the ratio peaked at 8 per cent in Korea, 19 per cent in Malaysia, 48 per cent in Thailand, and 49 per cent in Indonesia (Cortavarria et al. 2000).

4. Vila acknowledges that rapid aggregate deposit growth may reflect macroeconomic factors rather than excessive bank lending.

(1995, 1996) and Hawkins and Klau (2000) include hikes in interest rates to reflect government intervention intended to avert a crisis. They use a scoring system that maps the variables in the index onto five arbitrarily chosen bands.

These approaches, which essentially proxy stress with volatility measures, "have been criticized because they ignore potentially important information about the stochastic process that generates exchange rates" (Sauer and Bohara 2001, 135). The proposed solution has been to use autoregressive conditional heteroscedastic (ARCH) or general ARCH (GARCH) models, in the Engle (1982) and Bollerslev (1986) traditions, respectively, to proxy exchange rate volatility, because those models can take into account skewed distributions.

Sauer and Bohara (2001) proxy real exchange rate ($e_t$) risk in several ways, including using the conditional variance ($h_t$) of a first-order ARCH model,

$$ln(e_t) = a_0 + a_1 ln(e_{t-1}) + u_t,$$

where $u_t \sim N(0,h_t)$ and $h_{it} = b_0 + b_1 u^2_{t-1}$.

In addition, traditional Black-Scholes (1973) options pricing models can be used to back out implied currency volatility. Because of the forward-looking nature of option prices, implied volatility may act as a better gauge of risk and thereby a better proxy of stress in currency markets than traditional volatility measures.[5]

## 3.3 Debt crises/stress

Bordo and Schwartz (2000) characterize a debt crisis as the inability of sovereign nations or the broad private sector to service foreign debts. The majority of the literature on debt crises relates to a group of emerging economies that were exposed to severe external indebtedness in the early 1980s. These countries are identified mainly based on qualitative information. For example, in 1986 the then-U.S. Treasury Secretary James Baker identified 15 countries that were subject to external debt problems and therefore were the focus of attention under the so-called Baker plan (Kamin 1999; Dooley 1994).

5. The assumption of log-normality behind the Black-Scholes model limits its usefulness, however, particularly in modelling asset prices the distribution of which is non-normal or unknown.

## 3.4 Equity crises/stress

Most studies define equity crises as a sharp decline in the overall market index. The decline can be indicative of greater expected loss, higher dispersion of probable loss (higher risk), or increased uncertainty about the return of firms.

Risk can also be derived from ARCH or GARCH models, or from Black-Scholes options pricing models, as described above for currency markets. Patel and Sarkar (1998) identify equity-market crises in eight developed countries and 14 emerging-market countries using the CMAX method (a hybrid volatility-loss measure),

$$\text{CMAX}_t = x_t / \max [\, x \in (x_{t-j} \,|\, j = 0,1,....,T) \,],$$

where $x$ is the stock market index. The moving window is determined by $T$, and it is usually 1 to 2 years. That is, CMAX compares the current value of a variable with its maximum value over the previous $T$ periods. Vila (2000) uses the CMAX method to identify periods of sharp decline in the stock market, where the trigger level is chosen at either 1.5 or 2 standard deviations below the mean of the series. Some authors define crises based on judgment rather than standard deviations.

## 3.5 Overall financial crises/stress

There are few measures in the literature that resemble an overall FSI for developed countries. The Bank Credit Analyst (BCA) produces a monthly FSI for the United States, and it is the only other measure to actually call itself a stress index. Bordo, Dueker, and Wheelock (2000) construct a financial instability index, where their choice of variables makes it similar to a lagging stress index. Therefore, we refer to their index as an FSI for the remainder of this paper. JP Morgan produces a daily Liquidity, Credit and Volatility Index (LCVI), which resembles in many respects a stress index as defined in this paper.

The BCA's FSI for the United States is based on the following variables: (i) the performance of major U.S. banks' share prices relative to the overall market, (ii) short- and long-term quality credit spreads, (iii) private sector indebtedness, (iv) stock market leverage,[6] (v) overall stock market performance, (vi) consumer confidence,[7] (vii) the slope of the yield curve,[8] and (viii) stock and bond issuance.[9] The variables are measured as deviations from trend[10] and divided by

6. Stock market leverage is calculated in two ways: the market price-earnings ratio and the ratio of corporate debt to cash flow. Both yield very similar results after subtracting the mean and dividing by the standard deviation of each series.
7. "To capture the economic cycle and consumer stress" (McClellan 2001).
8. "As a measure of monetary policy" (ibid).
9. "As a measure of how well the market is functioning" (ibid).
10. Long-run and moving averages are both used, depending on the series.

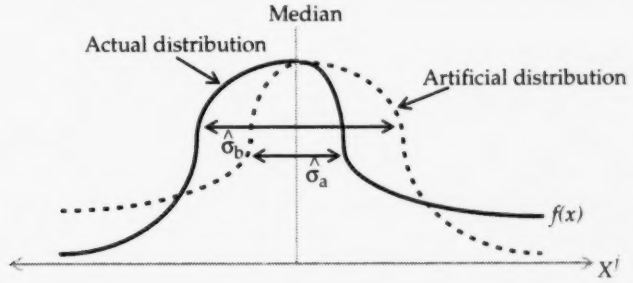
their historical standard deviations. The BCA's FSI is not based on a regression equation, because "it would be difficult to establish what the dependent variable should be" (McClellan 2001). High levels of the U.S. version of the index have been associated with financial turbulence of one kind or another. Figure 1 shows the result of applying the BCA approach to Canadian data.

The Bordo, Dueker, and Wheelock (2000) index includes: (i) bank failures, (ii) non-financial business bankruptcies, (iii) an ex post real interest rate, and (iv) an interest rate quality spread. Figure 2 illustrates the result of applying the Bordo, Dueker, and Wheelock technique to Canadian data. After the Great Depression, Bordo, Dueker, and Wheelock replace the U.S. bank failure rate with the aggregate net loan charge-off rate.[11] For the Canadian version, loan-loss provisions as a percentage of revenues are used. The variables are standardized and summed to form a composite index, as follows:

$$I_t = \sum_{j=1}^{J} \omega_j \frac{\left| X^j{}_t - \overline{X}^j \right|}{\hat{\sigma}_{a,b}},$$

where $\omega_j$ is the weight on each variable, $\overline{X}^j$ is the median of $X^j$, and $\hat{\sigma}_{a,b}$ is a specially calculated standard deviation. When $X^j{}_t$ is above the median, $\hat{\sigma}_a$ is the standard deviation of all the values of $X^j{}_t$ that are above the median and the same number of artificially generated equi-distant values that are below this median (Diagram 2). When $X^j{}_t$ is below the median, $\hat{\sigma}_b$ is the standard deviation of all $X^j{}_t$ that are below the median and the same number of equidistant values that are above the median. Similarly, Bordo, Dueker, and Wheelock define five classes of financial stress based on the deviation of this index from its subperiod median.[12]

**Diagram 2: Hypothetical Visual Demonstration of the Bordo, Dueker, and Wheelock (2000) "Standardization" Technique**




11. The value of loan charge-offs at commercial banks divided by total commercial bank assets.
12. Bordo, Dueker, and Wheelock also create a qualitative index based on a survey of historical sources.

The JP Morgan LCVI contains seven components: (i) the U.S. Treasury curve error (the rolling standard deviation of the spread between on-the-run and off-the-run U.S. treasury bills and bonds along the entire maturity curve), (ii) the 10-year U.S. swap spread, (iii) JP Morgan's Emerging Markets Bond Index (EMBI+), (iv) U.S. high-yield spreads,[13] (v) foreign exchange volatility,[14] (vi) equity volatility (VIX),[15] and (vii) the JP Morgan Global Risk Appetite Index.[16]

The index is constructed as follows. First, data for each variable are arranged to generate a sample cumulative distribution function (CDF). The data are then divided into percentiles based on this distribution. This transformation does not require the assumption of normality, as with standardized units (Prat-Gay and McCormick 1999). The transformed variables are then summed equally to create the overall LCVI. The index is benchmarked to its 50-day moving average, where values greater than one standard deviation above the benchmark are interpreted as a signal of systemic risk aversion (Caglayan 2002). However, no theoretical argument about investor preferences is made to justify this interpretation. Instead, we interpret the variables as measures of risk and expected loss.

The LCVI is shown in Figure 3. Note that time-series data for all of the LCVI components are available only from 1998 onwards and applied to global and U.S. markets, rather than the Canadian financial system specifically. Therefore, the LCVI is shown for interest, but is not used in subsequent empirical analysis.

## 4. Results of a Survey on Financial Stress in Canada

We conducted a survey of senior Bank of Canada policy-makers and economists to establish a consensus on which events have been the most stressful for Canadian markets over the past 25 years, and for what reasons. Forty questionnaires were distributed. Respondents included a former governor, three governing council members, eight senior bank officers, twelve bank officers, and three analysts. The questionnaire is shown in Appendix B.

---

13. B2-rated U.S. industrial companies.
14. The weighted average of 12-month implied volatilities of each of the euro, yen, Swiss franc, U.K. pound, Canadian dollar, and Australian dollar expressed in U.S. dollars and weighted by daily turnover.
15. The Chicago Board of Exchange equity volatility index (VIX). The VIX is based on the weighted average of the implied volatilities of eight equity option calls and puts.
16. The Global Risk Appetite Index (GRAI) is the Spearman's Rho (rank correlation) of foreign exchange excess return rankings, measured as the difference between future and spot prices for a basket of currencies at time $t$, and the risk ranking of those currencies based on their respective two-month yields up to time $t-1$ (Kumar and Persaud 2001).

## 4.1 Selecting a list of stressful events

The list of events was drawn from a review of every Bank of Canada *Annual Report* since 1977 and every *Monetary Policy Report* since 1995. Events were included if they were explicitly identified as having had a significant impact on Canadian markets. In some cases, events were broken into stages.

Nine events were largely Canadian in origin, including the mid-eighties bank failures, and the early-nineties real estate collapse and subsequent bank losses and trust failures/takeovers. A separate list was created for major Canadian-dollar events, including periods of heavy intervention, steep declines, and record lows. This was done to determine whether respondents viewed currency market stress as different from stress in other markets.

Twelve events were largely American in origin, including: the early-eighties bear market, October 1987 stock market crash, and the high-tech collapse of 2000; mid-eighties bank runs, Continental Illinois failure, the Savings and Loans crisis,[17] and the Long-Term Capital Management (LTCM) failure; the 1990 junk bond collapse; the currency accords of 1985 and 1987; and the 11 September 2001 terrorist attacks.

Thirteen events originated outside of North America. These included: the first and second less-developed country (LDC) crises in the early eighties; the 1990 Nikkei collapse; the early-nineties Scandinavian banking crises; the 1992 European exchange rate mechanism (ERM) crisis; the bond market turmoil of 1994; the 1994 Mexican, 1997–98 Asian, and 1998 Russian crises; the 1999 Brazilian réal devaluation; and the 2001 Turkish and Argentinian crises.

## 4.2 Events that were broadly perceived to be stressful

Table 2 lists the events that were deemed to be the most stressful for the Canadian financial markets. A clear consensus emerged from the survey that problems in the domestic banking sector have been very stressful. Despite their small size, the Canadian Commercial Bank (CCB) and Northland Bank failures in 1985 were seen to have had the potential to adversely affect the broader Canadian banking system. The large losses incurred by domestic banks as a result of the LDC crises were also noted. The first set of LDC bond defaults was seen as the pivotal stress event. As well, the real estate price collapse of the early 1990s and its impact on banks' balance sheets was considered to be very stressful. Nevertheless, these three events are difficult to tie to a

17. The Savings and Loans crisis cost U.S. taxpayers an estimated US$500 billion to US$1 trillion. Between 1988 and 1992, 882 U.S. banks went out of business.

specific date. For example, respondents felt that the potential (but ultimately unrealized) effects on the Canadian banking system created more stress than the actual failures of the small banks.

The second category of events that elicited a strong consensus was extreme market disruptions: the 1987 stock market crash,[18] 11 September 2001, the Mexican crisis, Russia's debt default, and the LTCM failure. Respondents felt that volatility was a factor, but not a sufficient condition, in making these episodes stressful. A broad-based loss of confidence seems to have been what set these events apart from other periods of price volatility.

The Asian crisis was generally considered to be stressful, although there are few linkages, real or financial, between Canada and these markets. The Asian crisis ranked well above the Nikkei crash of 1990, which eliminated 40 per cent of Japan's market capitalization. The Asian crisis precipitated a decline in commodity prices over the following year and a half, which resulted in a deterioration in Canada's macroeconomic fundamentals, and eventually helped trigger Russia's debt default.

The policy-induced spike in interest rates in 1981[19] was also widely viewed as very stressful.

## 4.3 Events that everyone agreed were not stressful

Few respondents felt that any of the U.S. or European banking events were very stressful for Canada. For example, the Savings and Loans crisis and the collapse of Continental Illinois were ranked 22 and 29 out of 40, respectively. Both had mean responses in the "not very stressful" range. This is not surprising, given that there were few direct linkages between these troubled institutions and the largely domestically owned Canadian financial institutions.

## 4.4 What is stress in foreign exchange markets?

Two-thirds of respondents felt that defending the Canadian dollar by increasing interest rates did not create stress in other interest-rate-sensitive markets. In fact, policy intervention was viewed as a way to reduce stress by restoring overall market confidence. A similar number felt that the dollar "hitting a new low" was not inherently stressful, despite the attention this receives in the media.

Four-fifths of respondents felt that sufficiently large exchange rate movements are usually stressful. Nevertheless, the eight most volatile periods for Canada's exchange rate over the past 25 years did

18. The TSE 300 lost 27 per cent of its value over a few days in October 1987. During the last three months of 1981 and the first half of 1982, the TSX lost almost 45 per cent of its value, but respondents felt this was gradual enough to not constitute high stress.
19. Five-year mortgage rates reached 21.75 per cent, and real short-term rates reached almost 9 per cent.

not receive particularly high rankings. It was far more likely that stress in other markets was perceived to lead to volatility in the Canadian dollar.

# 5. Selecting Variables for the FSI

There are two important elements in constructing an FSI: the choice of variables and the weighting scheme. This section deals with the variables; section 6 focuses on the weights.

Three alternative measures of financial stress are constructed. The first approach, called the standard measure, uses variables based on the literature review covering the banking, foreign exchange, debt, and equity markets. Second is the refined measure: where possible, refinements to the variables are considered, to better extract information about stressful periods. Third, GARCH estimation techniques (section 5.5) are used to extract volatility measures from price variables. Table 3 shows the variables contained in each of these measures.

Because a primary goal was to create a timely FSI that could be used for current analysis, the selection of variables is limited to those that are available on a daily basis.

## 5.1 Banking sector

*Standard measure*

In most of the literature on banking stress or crisis, no distinction is made between idiosyncratic shocks in the banking sector and economy-wide shocks. For example, bank profits, credit growth, and loan losses, which are cyclical, and bank share prices, which tend to be highly correlated with the overall stock market, are commonly used variables.

On the other hand, relative bank share prices tell us more about the idiosyncratic shocks that hit the banking sector. We use a conventional measure of relative equity-return volatility,

$$\beta = \text{cov}(r,m) / \text{var}(m),$$

where $r$ and $m$ are the total returns, at annual rates, to the banking sector index and the overall market index, respectively.[20] When $\beta$ is greater than 1, the volatility of total returns for bank

20. In this case, $\beta$ is calculated daily using a one-year rolling time frame. Shorter rolling periods produce a qualitatively similar, but noisier, $\beta$. $r$ and $m$ are calculated using the daily year-over-year change in the Toronto Stock Exchange (TSX) Bank & Trust Total Returns Index and the Standard & Poor's TSX (formerly the TSE 300) Total Returns Index, respectively. Both indexes are weighted by constituent market capitalization. Total Returns are defined as capital gains plus reinvested dividend disbursements. The respective price indexes, rather than total returns indexes, are used prior to 1986, due to data availability.

shares over the past year is greater than the volatility of total returns for the overall market. In this case, greater volatility is interpreted to mean that the banking sector is relatively riskier.

Several types of risk spreads are also considered to proxy stress in the banking sector (see section 5.3.1 on risk spreads). The most popular spreads used in the literature are medium- or long-term maturity subordinated bond yields, with the risk-free rate being the yield on government bonds with matching maturities. A time series for subordinated bank bond yields is not directly available for Canada, however. The closest available measures are corporate indexes with AA rated constituents, which in Canada are most representative of the risk ratings of banks and insurance companies.[21]

*Refined measure*

We impose two conditions on our refined measure of banking sector stress: (i) $\beta > 1$, and (ii) the return to the bank index is lower than the market return. These two conditions imply that the banking sector has a lower ex ante risk-adjusted return than the overall market, a potential signal of elevated stress. For $\beta \leq 1$ , or for superior performance, a value of zero is assigned to the refined variable.

## 5.2 Foreign exchange market

*Standard measure*

Foreign exchange stress manifests itself through several variables, depending on the type of exchange rate regime. The literature on currency crises deals almost exclusively with fixed or tightly managed exchange rates. In countries that have such exchange rates, stress results in significant losses of official reserves, increases in interest rates, and, if great enough, a collapse in the value of the currency.

According to our definition, stress can also occur when the exchange rate is floating. A depreciation represents a loss to domestic currency holders. Unexpected volatility creates uncertainty, which affects liquidity and thus the efficiency of the foreign exchange market. The standard approach in the literature is to use a volatility measure, or more commonly a hybrid volatility-loss measure such as the CMAX calculation. This paper uses the standard CMAX approach,

21. Scotia Capital and Merrill Lynch both provide corporate indexes for Canada by rating category but not by sector. Given that the major Canadian banks and insurance companies, which represent the bulk of financial institution assets, all have AA or A+ ratings, and that few other Canadian corporations do, we feel this is a reasonable approximation.

$$\text{CMAX}_t = x_t / \max [\, x \in (x_{t-j} \mid j = 0,1,...,T) \,],$$

with $T$ = one year (the most common time frame used in the literature).

*Refined measure*

A fluctuating currency is not necessarily a bad thing. Indeed, a floating exchange rate can alleviate macroeconomic stress by absorbing external shocks, which may outweigh the loss in the currency's value. Under these conditions, the standard approach may produce a false signal of stress. Therefore, to refine the standard approach, the exchange rate is benchmarked to its short-run fundamental value. Stress occurs when the exchange rate falls below its fundamental value (i.e., an overshooting depreciation). When the exchange rate rises above its fundamental value, the refined measure takes on a value of zero. This is consistent with the consensus in the literature that currency crises involve depreciations, and not appreciations. A significant appreciation may imply overvaluation, which we interpret as a leading indicator of stress, rather than a stressful event.

The Amano and van Norden (1995) and Djoudad and Tessier (2000) exchange rate model is used to approximate the Canadian dollar's fundamental value. The predicted value of the short-run Can$/US$ exchange rate is determined by,

$$\Delta \ln(rfx)_t = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c \ln(comtot)_{t-1} - \beta_e \ln(enetot)_{t-1}) + \gamma intdif_{t-1} + \theta \Delta debtdif_{t-1} - \varepsilon_t,$$

where *rfx* is the real exchange rate, *comtot* is an index of real non-energy commodity prices, *enetot* is an index of real energy prices, *intdif* is the Canada-U.S. 90-day commercial paper rate differential, and *debtdif* is the Canada-U.S. debt/GDP differential.

Because the model is based on fundamentals, the predicted value is assumed to approximate the fundamental value of the currency. We also experiment with statistical benchmarking techniques, such as the Hodrick-Prescott filter and autoregressive integrated moving-average (ARIMA) models, using nominal, real, and effective exchange rates. These result in qualitatively similar measures of stress, particularly during "peak" stress periods, as Figure 4 illustrates. The rapid depreciation of the Canadian dollar in 1985 and in the first half of 1986 is an exception. Statistically, it was one of the most severe depreciations in the post-war period. The Amano and van Norden model suggests that the depreciation was warranted by quickly deteriorating fundamentals, since the actual exchange rate does not significantly overshoot its predicted value. Thus, the level of exchange rate stress during this period was not high according to this measure.

## 5.3 Debt markets

### *5.3.1 Risk spreads*

The spread between risky and risk-free bond yields is a function of expected losses. Spreads can widen if expectations of future losses increase, or if greater uncertainty leads to lower confidence in the shape of the distribution, implying a higher dispersion of probable loss. Both factors are indicative of financial stress.

*Standard measure*

The covered Canada-U.S. 90-day treasury bill spread is used to proxy uncertainty in the domestic government debt market.[22] Assuming both obligations bear zero probability of default, the covered interest parity (CIP) condition states that there should be a zero spread. This leaves market uncertainty to explain any statistically significant divergences. Such divergences are indicative of greater stress.

A representative corporate bond spread is used to proxy risk in the corporate debt market.[23] Corporate yield spreads are a combination of credit, market, and liquidity risk premiums (Duca 1999). Credit risk is a function of expected loss, and market and liquidity risks are a function of risk and uncertainty. Therefore, any increase in the overall risk premium is indicative of greater stress.

*Refined measure*

A refined corporate risk spread is calculated by adjusting for fundamental macroeconomic factors. When the actual spread is above the fundamentally determined spread (i.e., the price of corporate bonds appears to be excessively low), it is indicative of financial stress. Otherwise, the refined measure takes a value of zero. We use the Elfner (2001) model to derive the fundamental value of Canadian corporate bond spreads.[24]

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22. Hedged using forward contracts.
23. The yield on the Scotia Capital all-Canadian corporate bond index with remaining maturities of 10 years or more minus government of Canada bonds with equivalent maturities.
24. The fundamental value is determined by four variables in a simple ordinary-least-squares regression with the corporate yield spread as the dependent variable; the variables are (i) Moody's Issuer Based Default Rate, (ii) the 10-year Government of Canada bond yield, (iii) the Bank Rate, and (iv) the Commodity Research Bureau's price index.

### 5.3.2 *Liquidity measures*

*Standard measure*

Turnover ratios and bid-offer spreads are both commonly used to gauge the liquidity of markets, but the latter is more readily available. The bid-offer spread on 90-day Government of Canada treasury bills is used to proxy liquidity risk in debt markets.[25] A lower level of liquidity is indicative of increased uncertainty on the part of market-makers.[26] Therefore, a higher bid-offer spread is interpreted as a sign of greater financial stress.

A second aspect of liquidity risk is called funding risk. A common measure of funding risk is the spread between the commercial paper rate and the treasury bill rate. This measure has been interpreted as a proxy for short-run disintermediation, or credit crunches, in some empirical work. For example, Gertler, Hubbard, and Kashyap (1990) for the United States, and Ng and Schaller (1996) for Canada, find evidence that the spread increases when information costs increase, such as during periods of uncertainty. Although default risk on prime non-financial commercial paper is extremely low even during recessions, creditors may seek shelter in the more liquid treasury market during such periods, reducing demand for commercial paper and thus pushing up spreads.[27]

### 5.3.3 *Deviations in short- from long-term interest rates*

*Standard measure*

We use an inverted yield-curve measure to proxy interest rate shocks, as in the BCA index. Implicitly, the long-run yield on government bonds is interpreted as the equilibrium interest rate. When short-term interest rates rise above this equilibrium (a negative yield curve), stress is exerted on debtors by increasing their short-term debt-servicing costs above the equilibrium level. In our case, we use the average of 5- to 10-year Government of Canada benchmark yields minus the 90-day commercial paper rate, because these are representative of yields and rates on actively traded long- and short-term debt, respectively, in Canada.

25. The data used to construct this series are based on midday surveys of dealers in Canadian government securities, beginning in August 1988. The spread is calculated as the difference between the lowest quoted bid rate and the highest quoted offer rate, even if these quotes come from different dealers. This optimal "inside" spread is probably unrealistically narrow, but it is the only one available.
26. Bid-offer spreads will also be affected by funding costs, which tend to rise quickly during periods of uncertainty.
27. Alternatively, the spread may reflect short-term expectations for monetary policy. The rationale is that, because commercial paper carries a fixed interest rate, firms may issue less (having a downward effect on rates) and substitute into variable-rate bank lines if they expect the overnight rate to fall within 30 or 90 days (depending on the commercial paper's maturity date).

## 5.4 Equity markets

*Standard measure*

Equity-market crises are most often measured by changes in stock market indexes or market capitalization. Trading volume, turnover ratios, new stock issuance, margin accounts, and the equity-risk premium also contain useful information about stress. As a first approximation, the CMAX calculation is used, which is common practice in the literature on emerging-market crises. This measure is based on the daily TSX index as a percentage of its one-year high, and can therefore be considered a hybrid volatility-loss measure.

*Refined measure*

The equity-market stress measure is refined by considering the equity-risk premium. Figure 5 shows three simple approaches to estimating the equity-risk premium. The premiums are based on equity valuation techniques described in Hannah (2000). A high equity-risk premium is interpreted as a sign of stress. A low equity-risk premium may indicate a stock market bubble, which would be interpreted as a *leading* indicator of stress, but not stress per se. This is consistent with the financial-crisis literature, which characterizes stock market crashes, not bubbles, as financial crises.

Our preferred version of the equity-risk premium uses the difference between the annual return to holding equities (the inverse of the forward price-to-earnings ratio, $E_{t+1}/P_t$) and the return to holding risk-free real return government bonds ($r$).[28] More formally,

$$\rho_t = \left[ \sum_{i=t}^{t+12} E_i \Big|_{\Omega_t} \right] / P_t - r_t,$$

where $\rho_t$ is the risk premium, and $\Omega_t$ is the market's information set at time t. As in Hannah (2000), the long-term Canada Real Return Bond yield ($r$) is used, rather than a nominal bond yield, since both earnings ($E$) and prices ($P$) are thought to rise with the overall price level. We assume a constant real return of 4.25 per cent before 1992, when the Real Return Bond did not exist.

28. This approach is derived from a simple valuation model alluded to in the Federal Reserve Board's *Monetary Policy Report to the Congress*, which accompanied the Humphrey-Hawkins testimony on 22 July 1997. Source: <http://www.federalreserve.gov/boarddocs/hh/1997/july/testimony.htm>.

Forward earnings are preferred to trailing earnings, because they contain information about expectations, despite their well-noted positive bias.[29] The dividend discount approach is not used in the FSI because, during the period under study, dividends were declining in importance.

## 5.5 Applying GARCH techniques to stress variables

Many studies have found that asset-price series such as stock indexes and exchange rates exhibit changes in variance over time (Bollerslev, Chou, and Kroner 1992). These changes tend to be serially correlated, with groups of highly volatile observations occurring together. It is very easy for the changes to occur, because a financial market in a state of uncertainty, such as the period shortly after a stock market crash, will take some time to reach its new equilibrium trading range. Conventional time-series models typically operate under the assumption of constant variance; thus they ignore this time-varying characteristic of asset-price volatility.

In this light, Engle (1982) introduces the ARCH process, to allow the conditional variance to change over time as a function of past errors while leaving the unconditional variance constant. The basic set-up of an ARCH model is to regard the series of interest, $y$, as being a sequence of independent, identically distributed random variables, $\varepsilon_t$, with unit variance, multiplied by a factor $\sigma$, the standard deviation,

$$y_t = \sigma_t \varepsilon_t ,$$

$$\varepsilon_t \sim IID(0, 1) .$$

$\sigma$ can be modelled in many different ways. The simplest possibility is to let

$$\sigma^2_t = \gamma + \alpha y^2_{t-1}, \quad \gamma > 0, \quad \alpha > 0 .$$

This simple ARCH model is not entirely satisfactory, because the conditional variance depends on only a single observation at $t$-1. As a result, many empirical applications of ARCH models specify a relatively longer lag, to allow the variance to change more slowly. Bollerslev (1986) proposes the GARCH model, which allows a longer memory and a more flexible lag structure,

$$\sigma^2_t = \gamma + \alpha_1 y^2_{t-1} + \alpha_2 y^2_{t-2} + \ldots + \alpha_p y^2_{t-p} + \beta_1 \sigma^2_{t-1} + \beta_2 \sigma^2_{t-2} + \ldots + \beta_q \sigma^2_{t-q} .$$

The simplest of such models is GARCH(1, 1), as follows:

$$\sigma^2_t = \gamma + \alpha_1 y^2_{t-1} + \beta_1 \sigma^2_{t-1} , \quad \gamma > 0 , \quad \alpha, \beta > 0 , \quad \alpha + \beta < 1 .$$

29. Expected earnings are aggregated by Thomson Financial I/B/E/S.

In the literature, stock prices are typically modelled with a GARCH(1, 1), GARCH(1, 2), or GARCH(2, 1) model, while exchange rate movements are mostly treated as a GARCH(1, 1) process (Bollerslev, Chou, and Kroner 1992). A GARCH(1, 1) framework is used to model the TSX stock price index, the bank stock price index as a share of the TSX, and the Can$/US$ exchange rate.[30] This technique allows us to better identify sudden "abnormal" movements in these series and discount the importance of the volatilities after the initial impact.

## 6. Combining the Variables into a Single Index

The choice of how to combine the variables (the weighting method) is perhaps the most difficult aspect of constructing an FSI. The difficulty in choosing weights lies in the lack of a reference series upon which different, meaningful weights can be derived and tested. Various weighting techniques are considered, including: factor analysis, credit aggregate-based weights, variance-equal weights, and transformations of the variables using their sample CDFs.[31] In all cases, the indexes are rebased such that they range in value from 0 to 100, with 100 being the maximum historical value of the index.

The variables are all measured on a daily basis, and values for the same day are combined. The decision to combine contemporaneous values, rather than leading and lagging values, is based on a series of simple statistical and econometric tests. First, 10 leads and lags[32] of each variable are regressed on each of the other variables in the index. Any significant leads or lags could signal a conditional non-contemporaneous relationship. Only a handful of leads and lags are statistically significant out of over 1200 tested.[33] The estimated coefficients on these leads or lags are then compared with the overall variation of the regressand, to test for spuriousness. None of the

30. We also experiment with GARCH(1, 2) and GARCH(2, 1) specifications. The results seem very similar to those from the GARCH(1, 1) model.

31. Another possible approach is to use implicit weights from simple non-linear probability models, such as probit and logit. Usually, these models are used to estimate probabilities, where the dependent variable is dichotomous. For the purposes of calculating implicit weights, however, both sides of the equation would be the same concept (i.e., financial stress), just measured in two different ways. The stress variables are continuous, and therefore would be placed on the right-hand side of the equation. The survey responses described in section 3 are dichotomous, and therefore would be placed on the left-hand side. The coefficients on the stress variables could then be interpreted as the vector of weights, and the estimated value for the variable on the left-hand side would be the implicit-weight FSI. There are numerous technical questions associated with this methodology that remain unanswered, so we leave this experiment for future work.

32. Ten leads and lags corresponds to one month of data at the business frequency, which seems to be a suitably long window to establish any relationship in daily variables.

33. Each variable in Table 3 was regressed against 10 leads and 10 lags of each of the other variables in its category (standard, refined, or GARCH), making 1220 unique lead/lag relationships to be tested.

statistically significant leads or lags is economically meaningful. A final test computes all of the unconditional cross-correlations between contemporaneous values of the variables. Correlations range from slightly negative for the overall equity-market measures and the bank beta (to be expected) to almost 50 per cent for the equity- and bond-market measures. Correlations tend to increase during stressful periods, but in no case rise above 50 per cent, suggesting that each variable contributes significant unique information. The conclusion, therefore, is that combining contemporaneous values of the variables is a reasonable approach.

## 6.1 Factor analysis

The basic idea of factor analysis is to extract weighted linear combinations (factors) of a number of variables. In a two-variable example, the principal factor of the two variables is the least-squared regression line between them. If one extends this example to multiple variables, one can extract many factors by rotating the scatter plot of the observations. The criterion for the rotation is to maximize the variance of the factor, while minimizing the variance around the factor, such that the first factor captures the most possible variances of the variables. Subsequent factors are extracted in the same fashion to account for the remaining variances.

This technique has two main purposes: (i) to reduce the number of variables, and (ii) to detect the structure in the relationships between variables. Many studies have applied factor analysis to a large number of explanatory variables in forecasting models. For example, Stock and Watson (1999) forecast GDP with a few factors derived from 215 monthly indicators, and find that the factor model outperforms various benchmark models. Combining the information content in 334 Canadian and 110 U.S. macroeconomic variables into a few representative factors, Gosselin and Tkacz (2001) find that factor models perform as well as more elaborate models in forecasting Canadian inflation.

The factor analysis approach in this paper is partly motivated by the Chicago Fed National Activity Index (CFNAI). Following the techniques of Stock and Watson (1989, 1999), the Federal Reserve Bank of Chicago (2000) builds the index with factors from 85 monthly economic indicators. The CFNAI is designed to be an alternative to GDP as a measure of the level of economic activities. In theory, a similar index may also be derived to measure stress, reflecting the structural movements in a group of financial variables. It is tempting to include all variables described in Table 1 as well as those that are believed to move contemporaneously with stress; for example, bank profits and consumer confidence. Subject to data timeliness and availability, only daily variables are considered. Factor analysis is applied to the three versions of the FSI: standard,

refined, and GARCH, using the principal-component technique proposed in Gosselin and Tkacz (2001).

## 6.2 Credit weights

A second approach weights the variables by the relative size of each market to which they pertain. The larger the market as a share of total credit in the economy, the higher the weight assigned to the variable proxying stress in that market. Therefore, the weights have some economic meaning. Since the relative size of each market varies over time, a chain-linked weighting scheme is used.

Total credit in the economy is measured by the sum of bank credit, corporate bonds, government bonds, equities, and U.S.-dollar credit (Figure 6).[34] U.S.-dollar credit is the amount of loans to, and bonds issued by, Canadian residents denominated in U.S. dollars. For markets with more than one stress proxy, the corresponding weight is split evenly.

## 6.3 Variance-equal weights

A variance-equal weighting method generates an index that gives equal importance to each variable. It is the most common weighting method used in the literature. The variables are assumed to be normally distributed, which is the primary drawback of this approach. The mean is subtracted from each variable before it is divided by its standard deviation, hence the term "variance-equal" weights.[35] Both the arithmetic and geometric means of the variables are considered in this paper. An index that uses the geometric mean and is chained monthly has the desirable property of transitivity, which is not necessarily the case with the arithmetic mean. Furthermore, the geometric mean is preferable when weights are unknown. On the other hand, the components are standardized with mean zero, and, since the geometric mean requires positive values, half of the observations must be ignored. This may not be a serious problem, if one is concerned primarily with above-average values of stress.

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34. Where bank credit is the sum of consumer credit, residential mortgages, business loans, non-residential mortgages, bankers' acceptances, leasing receivables, and loans to the public sector, Bank of Canada series B127, B982, B2322, B2303, B2327, B2308, and B399, respectively; corporate bonds is the Bank of Canada series B2318; government bonds includes federal, provincial, and municipal issues; equities is Bank of Canada series B2319.
35. Historical data for bid-offer spreads were not available prior to 1988, so the pre- and post-1988 weights are adjusted accordingly.

## 6.4 Transformations using sample CDFs

A somewhat similar approach to combining the variables uses a transformation based on their sample cumulative distribution functions (CDFs), rather than assume normality by standardizing. First, each variable is transformed into percentiles based on its sample CDF, such that the most extreme values, corresponding to the highest levels of stress, are characterized as the 99th percentile. The smallest values, corresponding to the lowest levels of stress, are characterized as the first percentile. Values about the median are characterized as the 50th percentile, and so on. The transformed variables are unit-free and implicitly reflect all the moments of their distributions, provided they are time stationary, regardless of whether the distribution is normal (Prat-Gay and McCormick, 1999). (Recall that section 5.5 uses GARCH methods for variables with conditional variances.) The transformed variables are then averaged using both chain-linked arithmetic and geometric means. A value of 99 for the overall index corresponds to extreme high levels of stress for all variables.

## 6.5 Comparison of weighting methods

Three quarters of the cross-correlations (Table 4) between the variously weighted stress indexes increased during stressful periods. The correlations are also reasonably high, averaging 71 per cent during stressful periods, but only 59 per cent during non-stress periods. Of the five different weighting methods, factor analysis produces results that are not only less correlated during stressful periods, but also not very highly correlated with the other measures. Nevertheless, Figure 7 illustrates how qualitatively similar the results are when two very different weighting techniques (credit aggregate weights and factor analysis[36]) are applied to the standard stress variables.

Figures 8 and 9 illustrate two of the many possible methods of combining the subcomponent stress variables. The refined stress variables shown in Figure 8 are depicted proportionately to their weight in the overall FSI at the bottom, using variance-equal weights. Similarly, the standard stress variables in Figure 9 are depicted proportionately using credit aggregate weights. The reasons for choosing these two versions are described in section 7.

36. First extracted factor.

# 7. Which Index is Best?

The survey results have established a qualitative benchmark with which to compare and evaluate the various stress measures where no benchmark was previously available. Table 5 presents some summary statistics upon which a comparison might be made.

In the EWI literature (Appendix A), crisis indicators are often evaluated on their Type I and II errors. Type I errors are the probability of failing to signal a crisis. Type II errors are the probability of falsely signalling a crisis. The policy-maker will minimize these errors according to its desired loss function. This paper uses similar probabilistic evaluation criteria where results of the survey are deemed to represent "true" high-stress events. Therefore, the probability that a measure fails to capture a high-stress event is,

$$TypeI = prob(X < \tau | C = 1) ,$$

where $X$ is the quantitative measure of stress with threshold $\tau$; and $C$ is a binary variable that equals 1 if survey respondents felt Canadian financial markets were under stress during the month in question, and 0 otherwise. Similarly,

$$TypeII = prob(X > \tau | C = 0) .$$

The threshold $\tau$ can be varied to conduct sensitivity analysis. Table 5 uses a threshold of plus-one standard deviation above the median. As the threshold is raised, the Type I errors increase, and Type II errors decrease. For example, using $\tau = +2\sigma$ increases Type I errors by 8.6 percentage points on average, and reduces Type II errors by 6 percentage points on average. A two-standard-deviation threshold cuts off about 95 per cent of the sample, depending on the measure. The choice of $\tau$ does not significantly alter the ordinal ranking of the measures.

## 7.1 Evaluating overall stress measures

As Table 5 indicates, the BCA and Bordo, Dueker, and Wheelock (2000) styles of FSI fail to capture a large number of stressful events highlighted by the survey. This is not surprising, since both measures use variables that appear to be more cyclically influenced than event-driven. For example, the BCA's FSI uses consumer confidence, the long-term yield curve, and several debt measures. The Bordo, Dueker, and Wheelock style FSI uses bank loan-loss rates and corporate bankruptcies, which tend to lag the economic cycle.[37]

37. As stated earlier, Bordo, Dueker, and Wheelock call their measure a financial *instability* index, but we feel it conforms more closely to our definition of an FSI, except with lagging measures of stress.

On the other hand, nine of the eleven stress measures that are calculated in this paper outperform the BCA and Bordo FSIs in terms of Type I errors. Many of the variables in these stress measures capture extreme movements, usually in market prices, driven by short-term shocks. Most of the standard and refined stress measures capture 75 to 85 per cent of the stressful events highlighted by the survey. The GARCH variable indexes do not perform as well. The factor-analysis weighting technique performs poorly, with high Type I errors.

Every empirical index of stress we consider, including the Bordo and BCA indexes, shows a spike in 1984, which does not correspond to survey responses. Respondents were asked to rank two events in 1984: the bank run on Continental Illinois and the depreciation of the Canadian dollar to 74.9 U.S. cents (at the time, its lowest level in history). Neither event was ranked as very stressful for the Canadian financial system. In hindsight, two other notable events in 1984 that were not explicitly mentioned in the survey perhaps should have been. World oil prices fell by almost 10 per cent owing to quota cheating by OPEC members, which indirectly affected Canadian financial institutions via a sharp deterioration in the value of real estate loans and oil-related debt and equity in western Canada. Also, Canadian interest rates rose sharply through the year, a result of "the reaction in U.S. financial markets to the rapidly expanding U.S. economy, the associated high rates of growth of money and credit and the policy response of the U.S. monetary authorities."[38] Based on a visual inspection of the variables used in the various indexes, it appears that the indirect effects of the oil-price shock and the sharp increase in interest rates are the primary reasons for the observed spike in stress in 1984.

In terms of best overall performance, the credit-weighted standard-variable index has the lowest Type I error, at 13 per cent, and the lowest Type II error, at 33 per cent. This is one of the simplest indexes to construct of the thirteen considered. Since it performs well and is simple to interpret and communicate, we suggest that it be used as the FSI for Canada and tested further.

## 7.2 Evaluating individual market measures

The factors influencing innovations in the various FSI measures are probably of greater analytic interest. Table 6 breaks the FSIs down into their subcomponents and compares their Type I and Type II error performance with crisis variables commonly used in the literature (section 3). The crisis variables, most of which are binary and have until now been applied only to emerging-market countries, are constructed using Canadian data. The high stress or crisis threshold ($\tau$) is chosen based on the threshold suggested by the source in the literature, or on plus-one standard

38. Bank of Canada *Annual Report*, 1984.

deviation if no explicit threshold is stated for stationary series, or on the upper Bollinger Band for non-stationary series.[39]

The most striking result is the size of the Type I errors associated with the binary crisis variables that form the basis of most research on EWI models. Although these variables were not intended to be applied to industrialized countries, this result brings into question the relevance of existing EWIs for a country such as Canada. It also suggests a completely novel approach to predicting financial distress will be required for Canada.

The Type I errors are also fairly high for the individual variables used in the FSIs. On average, between one-third and half of the market-specific events identified as very stressful by survey respondents were not identified as such by the respective market variables.

### *7.2.1 Evaluation of the banking sector measures*

The survey identified three stressful episodes for the Canadian banking sector: the LDC loan losses (which coincided with domestic and global interest rate volatility in the early 1980s); the CCB and Northland Bank failures, and their subsequent effects on other small banks; and the 1992 peak in loan losses (largely due to commercial real estate).[40] The Vila (2000) CMAX and standard FSI variables captured the loan-loss periods, but both "failed" to signal the small-bank failures and subsequent effects as high-stress events (hence the 50 per cent Type I error rate). The failures and their aftershocks appear to have been too small to disrupt markets, and hence did not create stress in the system according to these empirical measures.

We prefer the standard FSI measure (a combination of bank share $\beta$'s and bond yield spreads), over the bank share price measure from Vila (2000), although both have the same Type I errors. The latter is too sensitive to overall equity-market movements, which may not reflect stress specific to the banking sector.

### *7.2.2 Evaluation of the foreign exchange measures*

Although there was no clear consensus on when, if at all, Canadian foreign exchange markets have come under stress, we exercise some judgment and interpret respondents' comments to determine the following test periods: the 1984 oil-price collapse (which affected Canada's terms

39. The upper Bollinger Band is the moving average plus one standard deviation of a series. The moving window is dictated by the time-varying moments of the series.

40. The exact dates are: March to December 1982, September 1985 (CCB and Northland failures) to March 1986 (effects on other small banks), and 1992 (fallout from the real estate collapse and trough in the credit quality cycle for the banks).

of trade), the 1985 pre-Plaza turmoil, the European ERM crisis, the peso crisis, the Asian crisis, and the Russian/LTCM crisis.[41]

The standard CMAX measure seems to provide the best match with the survey. This simple measure is good at capturing large declines in the exchange rate over a 12-month horizon, which occurred during the above episodes. The GARCH volatility measure, which captures large movements from day to day, performed almost as well. Therefore, a combined measure of depreciation and volatility would seem to best capture exchange rate stress.

One might argue that stress in the foreign exchange market is distinct because, over the period under examination, monetary policy may have responded to this type of stress differently (for example, by raising interest rates to offset inflationary pass-through effects). Figure 10 compares the FSI, excluding the exchange rate variable, with those episodes of foreign exchange stress highlighted by survey respondents. In 1984 and 1985, there were two high-stress foreign exchange episodes when all of the other markets appeared to be calm. However, during the 1992 ERM crisis, the 1995 peso crisis, the 1997–98 Asian crisis, and the 1998 Russian and LTCM crises, the index (based on non-foreign exchange variables) reaches high levels.

To the extent that financial stress and currency stress appear to be highly contemporaneous over the past 15 years, and because survey respondents drew a link between stress in other markets and the currency market, it seems reasonable to use a single FSI to capture stress in all four major markets. Figure 11 illustrates, in fact, that, because of the high correlation of stress across markets, the inclusion or exclusion of foreign exchange stress does not alter the FSI significantly. This also holds true when the weights on the foreign exchange measures are doubled and tripled.

### *7.2.3 Evaluation of the equity-market measures*

The GARCH measure performs the best in identifying stock market stress, and confirms that the October 1987 stock market crash was the most severe stress event.[42] Interestingly, none of the measures identified 11 September 2001 as a high-stress event for equity markets. The TSX fell sharply when it reopened on 13 September (the 49th largest daily decline for the index since 1956), but volatility was not extreme afterwards. Similarly, measures of the equity-risk premium did not increase significantly. Although new share issuance was weak, it had been weak long

41. The exact dates relevant to Canada are: February 1984, February 1985, September to December 1992 (ERM crisis), December 1994 to January 1995 (peso crisis), February to April 1998 (Asian crisis), and September to December 1998 (Russian/LTCM crisis).

42. The exact dates relevant to Canada are: October 1987, September to December 1998 (Russian/LTCM crisis), September to December 2000 (high-tech collapse), and September to December 2001 (11 September).

before September. And share turnover was clearly zero during the time the market was closed. This explains why none of the equity-market variables that we considered isolated 11 September as a particularly stressful episode.[43]

### *7.2.4 Evaluation of the debt-market measures*

The FSI standard measures of debt-market stress have the lowest Type I and II errors.[44] The refined measure uses the same variables, except that it adjusts the corporate bond spread using the Elfner (2001) valuation model. This adjustment alone increases the Type I error by 20 percentage points. Given the added problem of model uncertainty, there is considerable room to improve this refinement in future work.

Empirically, the Asian crisis was not identified as being immediately stressful. On the other hand, the Russian/LTCM crisis appeared to be very stressful, regardless of the measure used. It can be argued that the Asian crisis precipitated Russia's debt default through a negative-terms-of-trade shock, which was the same channel that transmitted stress to Canadian markets.

## 7.3 How to interpret the level of the FSI

A primary goal of the FSI is to provide a "snapshot" of the current degree of stress in the financial system. Nevertheless, interpreting the index remains a challenge. In this section, we address only some of the important issues.

Since the FSI is mean-reverting by construction, the level of the index should provide more useful information than its growth rate. In particular, we focus on the stress levels above the mean. These observations indicate higher than "normal" stress levels. The change in the index over a certain time period also provides useful information on the evolution of stress; for example, whether there has been a sharp crash in the stock market or a gradual deterioration.

Since each variable in the FSI is standardized, the level of stress for a current event can be compared only with that of an historical event in terms of their deviations from the mean. The value of the index is likely to change when the sample period is altered, but the ordinal ranking of two events should remain the same.

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43. On the other hand, several of the debt-market variables clearly singled out 11 September as stressful, so the overall FSI does reach extreme values during the month.
44. The exact dates relevant to Canada are: March to December 1982 (LDC crisis), fourth quarter 1992 (peak of corporate bond defaults), December 1994 to January 1995 (peso crisis), and September to December 1998 (Russian/LTCM crisis).

Simple benchmarks are assigned to the FSIs and their subcomponents to signal a high degree of stress. In the literature, the choice of similar benchmarks has been largely ad hoc. We propose to use a one-tailed two-standard-deviation threshold (97.5 per cent confidence level under a normal distribution). It isolates the events that were considered the most stressful in the survey.

By definition, the FSI captures the contemporaneous level of stress and is not expected to have strong predictive power for future stresses or crises. Leading indicators of these events, which may include lagged values of the FSI or its components, can be identified from models using the FSI as the dependent variable.

One might expect financial stress to be inversely correlated with consumer and business confidence measures. Figure 12 plots the FSI against the percentage of Canadian consumers surveyed by the Conference Board of Canada who felt they would be financially worse off over the next six months. The correlation between the FSI and consumer confidence appears to be higher during recessions. There was a small deterioration in confidence coinciding with the 1998 Russian/LTCM crisis. However, the 1987 stock market crash appears to have had little effect on consumer sentiment. Figure 13 plots the FSI against the percentage of Canadian firms surveyed by the Conference Board of Canada that expected their financial situations to worsen over the next six months. This measure of business confidence is also highly cyclical. It demonstrates stronger relationships with the FSI during recessions, and does not appear to be strongly coincident with major financial stress events. The sampling frequency and timing of the confidence surveys may affect these results.

## 8. Concluding Remarks

Several versions of the FSI compare favourably with measures commonly used in the literature by providing a better match with the results of our survey. We prefer the standard-variable version, using the credit aggregate weighting technique, because its components are simple to interpret and communicate, it has economically meaningful weights, and it has the lowest Type I and Type II errors.

The FSI provides an ordinal measure of stress in the financial system. It is, however, a preliminary attempt to quantify the stress spectrum. At the moment, changes in the FSI are useful in evaluating whether stress is rising or falling, and in establishing time frames for extreme events.

We encourage future research on Canadian financial stability to use the FSI as a reference series. Since the FSI is a continuous-valued series, it could be more informative in developing an EWI model than a standard dichotomous crisis variable. The FSI could be regressed on a number of

lagged variables that are believed to possess leading information about stress or crises. The results could then be used to construct measures of financial fragility, which indicate the likelihood that an exogenous shock will affect the degree of stress, given perceived vulnerabilities in financial structures and conditions (see Diagram 1 on page 3).

Another extension could be to use the FSI to explain changes in real economic variables, such as GDP and investment. By definition, extremely high levels of financial stress impair not only the financial system but also result in significant losses in the real economy. Lower levels of stress may also affect the real economy to a lesser extent: for example, they could result in tight liquidity conditions and asset-price instability, both of which could lead to an increase in the cost of capital and reduce private investment and consumption.

One could also extend the methodologies developed in this paper to create FSIs for other countries. Validating the results would be difficult, however, without conducting a comparable survey of financial experts in those countries. Provided such FSIs could be developed, a weighted combination—based, for example, on financial or trade linkages—could be useful for analyzing financial contagion and for assessing the external environment faced by the Canadian financial system. This could serve as a useful tool in domestic macroeconomic and financial analysis.

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**Table 1: Variables that Contain Information about Financial Stress**

Based on a review of the EWI literature and authors' suggestions. This list is not intended to be exhaustive.

| | Market | | | |
|---|---|---|---|---|
| | Banking | Foreign exchange | Debt | Equity |
| **Quantity variables** | Erosion of capital, deposit insurance payouts, central bank emergency loans or official bailouts, non-performing loans, loan-loss provisioning | Reserve losses IMF loans or other international loan packages, turnover | Turnover on secondary markets, net new issuance, use of first-loss and liquidity provisions in securitizations | Market turnover, net new issuance, increased use of margin accounts, erosion of market capitalization |
| **Price variables** | | | | |
| Asset prices | Bank share prices bank bond yields | Spot and future prices | Bond yields | Equity prices |
| Risk measures | z-scores yield, swap, and intermediation spreads | Implied volatility, bid-ask spreads | Yield spreads, bid-ask spreads | Implied volatility, bid-ask spreads, equity premium |
| **Other signs of stress** | Bank runs, failures, suspensions, downgrades or other ratings actions, deposit restrictions | Imposition of capital controls | Bankruptcies, defaults, ratings downgrades, use of guarantees or other credit derivatives | Market closures, fewer IPOs or M&A activity, ratings downgrades |

**Table 2: Events Deemed to be the Most Stressful to Canadian Financial Markets**

Based on an internal Bank of Canada survey of senior policy-makers and economists. The rank is based on the highest mean value (rounded values are shown).

| Event | Rank (out of 40 events) | Mean (on a scale from 1 to 3) | Mode (on a scale from 1 to 3) | % of respondents who ranked the event |
|---|---|---|---|---|
| October 1987 stock market crash | 1 | 2.6 | 3 | 96 |
| Reputational aftershocks from bank failures (1985–86) | 2 | 2.6 | 3 | 88 |
| Events of 11 September 2001 | 3 | 2.6 | 3 | 96 |
| LDC crises (early 1980s) | 4 | 2.6 | 3 | 96 |
| early-1990s bank losses | 5 | 2.4 | 3 | 92 |
| August 1981 spike in interest rates | 6 | 2.4 | 3 | 88 |
| Asian crisis (1987–98) | 7 | 2.4 | 3 | 100 |
| CCB and Northland failures (1985) | 8 | 2.3 | 3 | 92 |
| Mexican crisis (1994–95) | 9 | 2.3 | 3 | 100 |
| Russian debt default (1998) | 10 | 2.2 | 2 | 100 |
| LTCM collapse (1998) | 11 | 2.2 | 2 | 100 |
| High-tech price collapse (2000) | 12 | 2.1 | 2 | 100 |

**Table 3: Selected Variables for the FSI**

The variables below are scaled by their centred standard deviations.

| | FSI standard variables | FSI refined variables | FSI GARCH variables |
|---|---|---|---|
| Banking sector | $\beta = \text{cov}(r,m)/\text{var}(m)$ calculated daily over a rolling 1-year time horizon, where<br>$r$ = year-over-year percentage change in the TSX Bank & Trust Total Returns Index (formerly the TSE Bank & Trust Total Returns Index; source: Datastream). Prior to 1986, the year-over-year percentage change in the TSE Bank & Trust Price Index (source: Toronto Stock Exchange).<br>$m$ = year-over-year percentage change in the S&P/TSX Total Returns Index (formerly the TSE 300 Total Returns Index; source: Datastream). Prior to 1986, the year-over-year percentage change in the TSE 300 Price Index (source: Toronto Stock Exchange). | $\beta$ as calculated in the FSI standard version, but only when $\beta > 1$ and then only when $r < m$. | GARCH (1,1) volatility of relative bank share prices ($BX/TSX$),<br>$BX$ = TSX Bank & Trust Price Index (formerly the TSE Bank & Trust Price Index; source: Toronto Stock Exchange).<br>$TSX$ = S&P/TSX Price Index (formerly the TSE 300 Price Index; source: Toronto Stock Exchange).<br><br>See section 5.5 for more details. |
| | Bank bond yield spread (approximated with the AA-rated long-term corporate bond yield, of which most constituents are financial issuers, minus the Government of Canada long-term bond yield; source: Scotia Capital). | Same as FSI standard. | Same as FSI standard. |
| Foreign exchange market | $canC6_t / \max[canC6 \in (canC6_{t-j} \mid j = 0,1,\ldots,T)]$ where T = 365.<br>That is, the daily value of the Canadian effective exchange rate ($canC6$) as a per cent of its maximum value over the preceding 365 calendar days (i.e., the CMAX method).<br>$canC6$ = a weighted combination of the U.S. dollar (85.84%), the euro (5.95%), the Japanese yen (5.27%), the U.K. pound (2.17%), the Swiss franc (0.42%), and the Swedish krona (0.35%). Source: Bank of Canada. | The short-run predicted value for the Canada/US dollar exchange rate minus the actual value, expressed as a percentage. A value of zero is assigned if the actual exchange rate is above the short-run predicted value. Source: Bank of Canada. See section 5.2 for more details. | GARCH (1,1) volatility of the Canadian effective exchange rate ($canC6$).<br><br>See section 5.5 for more details. |

(continued)

**Table 3: Selected Variables for the FSI**

The variables below are scaled by their centred standard deviations.

| | | | |
|---|---|---|---|
| Equity market | $TSX_t$/max[$TSX \in (TSX_{t-j} \mid j = 0,1,...,T)$] where T = 365. That is, the S&P/TSX Price Index (formerly the TSE 300 Price Index) as a per cent of its maximum value over the preceding 365 calendar days (i.e., the CMAX method). Source: Toronto Stock Exchange. | $\rho_t = E_t / TSX_t - r_t$<br>$\rho_t$ = the S&P/TSX equity risk premium at time $t$.<br>$E_t$ = consensus analysts' forecasts of 12-month forward earnings as at time $t$ (source: Thomson Financial I/B/E/S) for the S&P/TSX (formerly the TSE 300).<br>$TSX_t$ = as per FSI standard.<br>$r_t$ = The Government of Canada Real return benchmark long-term bond yield at time $t$ (source: Bank of Canada). A constant real return of 4.25% is assumed prior to 19 November 1991, when this series began. | GARCH (1,1) volatility of the S&P/TSX Price Index (formerly the TSE 300 Price Index; source: Toronto Stock Exchange).<br><br>See section 5.5 for more details. |
| Debt market | Corporate bond yield spread (All-rated long-term corporate bond yield minus the Government of Canada long-term bond yield; source: Scotia Capital). | Corporate bond yield spread (as calculated for the FSI standard version) but only when it is below "fair value" spread as described in Appendix C. A value of zero is assigned if the actual spread is above its "fair value." | Same as FSI standard. |
| | Canada-US covered interest rate differential<br>$(1 + r_t^*) = F_t/S_t^* (1 + r_t)$<br>$r^*$ = U.S. Government 90-day Treasury bill rate as at noon on day $t$<br>$F_t$ = 90-day forward rate for the US-Canada dollar exchange rate as at noon on day $t$<br>$S_t$ = spot rate for the US-Canada dollar exchange rate as at noon on day $t$<br>$r_t$ = Government of Canada 90-day Treasury bill rate as at noon on day $t$<br>Source: Bank of Canada. | Same as FSI standard. | Same as FSI standard. |
| | Liquidity spread<br>Government of Canada 90-day Treasury bill bid-offer spread, 30-day moving average (source: Bank of Canada). | Same as FSI standard. | Same as FSI standard. |

(continued)

**Table 3: Selected Variables for the FSI**

The variables below are scaled by their centred standard deviations.

| | | | |
|---|---|---|---|
| | Commercial paper spread<br>Canadian 30-day commercial paper rate minus 30-day Treasury bill rate (source: Bank of Canada). | Same as FSI standard. | Same as FSI standard. |
| | Inverted yield curve<br>the average of 5-10 year Government of Canada benchmark bond yields minus the Canadian 90-day commercial paper rate (source: Bank of Canada). | Same as FSI standard. | Same as FSI standard. |

## Table 4: Cross-Correlations of Stress Measures (in per cent)

Correlations during stress periods (based on section 6 results) are shown on the upper diagonal. Correlations during non-stress periods are shown on the lower diagonal. Shaded values denote greater correlation during stressful periods.

| | | | Standard variables | | | | | Refined variables | | | | | GARCH variables | | | | | BCA FSI | Bordo et al. FSI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **weight method** | arith. mean | geo. mean | credit agg. | sample CDF | factor analysis | arith. mean | geo. mean | credit agg. | sample CDF | factor analysis | arith. mean | geo. mean | credit agg. | sample CDF | factor analysis | | |
| Standard variables | Variance equal | arithmetic mean | | 85 | 99 | 94 | 57 | 90 | 80 | 90 | 61 | 62 | 85 | 76 | 82 | 85 | 49 | 66 | 45 |
| | | geometric mean | 82 | | 84 | 79 | 33 | 74 | 70 | 72 | 36 | 58 | 76 | 86 | 75 | 74 | 33 | 50 | 36 |
| | credit aggregate | | 97 | 85 | | 92 | 54 | 89 | 78 | 91 | 62 | 63 | 89 | 79 | 91 | 81 | 47 | 56 | 33 |
| | sample CDF | | 93 | 80 | 93 | | 66 | 88 | 75 | 87 | 67 | 73 | 81 | 68 | 80 | 83 | 52 | 72 | 53 |
| | factor analysis | | 58 | 51 | 59 | 67 | | 50 | 42 | 47 | 77 | 40 | 51 | 40 | 70 | 49 | 81 | 54 | 47 |
| Refined variables | Variance equal | arithmetic mean | 76 | 65 | 76 | 74 | 56 | | 87 | 99 | 65 | 76 | 85 | 70 | 85 | 72 | 38 | 61 | 41 |
| | | geometric mean | 61 | 72 | 67 | 60 | 48 | 83 | | 84 | 54 | 70 | 81 | 66 | 81 | 66 | 22 | 60 | 46 |
| | credit aggregate | | 75 | 68 | 80 | 78 | 58 | 98 | 83 | | 64 | 76 | 87 | 71 | 88 | 71 | 36 | 53 | 36 |
| | sample CDF | | 52 | 51 | 59 | 60 | 72 | 67 | 61 | 71 | | 52 | 53 | 55 | 64 | 64 | 16 | 51 | 34 |
| | factor analysis | | 60 | 46 | 67 | 68 | 63 | 80 | 71 | 84 | 64 | | 59 | 39 | 59 | 57 | 71 | 38 | 15 |
| GARCH variables | Variance equal | arithmetic mean | 70 | 58 | 71 | 73 | 66 | 66 | 51 | 69 | 71 | 51 | | 87 | 99 | 87 | 46 | 19 | -1 |
| | | geometric mean | 41 | 41 | 41 | 43 | 47 | 35 | 35 | 37 | 43 | 29 | 76 | | 86 | 78 | 42 | 12 | -3 |
| | credit aggregate | | 70 | 64 | 74 | 73 | 65 | 68 | 57 | 72 | 70 | 56 | 98 | 75 | | 83 | 44 | 14 | -5 |
| | sample CDF | | 61 | 48 | 61 | 65 | 61 | 55 | 38 | 58 | 62 | 39 | 93 | 71 | 93 | | 68 | 58 | 46 |
| | factor analysis | | 43 | 34 | 40 | 46 | 70 | 31 | 21 | 32 | 36 | 45 | 71 | 64 | 69 | 75 | | -21 | 3 |
| BCA Financial Stress Index | | | 30 | 20 | 26 | 29 | 30 | 18 | 9 | 12 | 16 | 7 | 13 | 4 | -12 | 4 | 23 | | 85 |
| Bordo et al. FSI | | | 32 | 22 | 25 | 30 | 8 | 8 | 1 | 7 | 4 | -9 | -7 | -13 | 3 | -11 | 29 | 75 | |

Note: The BCA and Bordo, Dueker, and Wheelock (2000) FSIs are based on their respective U.S. methodologies using Canadian data as closely matched in definition as possible. Neither the BCA nor Bordo and his co-authors actually construct a Canadian FSI. Weighting methods compared above are the arithmetic mean, geometric mean, and weights derived from credit aggregates.

### Table 5: How Closely do the Stress Measures Match the Survey Results?

The stress measures are compared with the survey results using two criteria: (i) the Type I error, the probability of failing to report a high-stress event, and (ii) the Type II error, the probability of falsely reporting a high-stress event. Shading denotes a variable with the lowest Type I error.

| | | | Type I error (%) "failure rate" | Type II error (%) "false positive rate" |
|---|---|---|---|---|
| Standard variables | Variance equal | Arithmetic | 15 | 41 |
| | | Geometric | 22 | 43 |
| | Credit aggregates | | 13 | 33 |
| | Sample CDF | | 22 | 42 |
| | Factor analysis | | 45 | 41 |
| Refined variables | Variance equal | Arithmetic | 22 | 38 |
| | | Geometric | 25 | 38 |
| | Credit aggregates | | 27 | 36 |
| | Sample CDF | | 44 | 48 |
| | Factor analysis | | 42 | 42 |
| GARCH variables | Variance equal | Arithmetic | 27 | 40 |
| | | Geometric | 32 | 41 |
| | Sample CDF | | 33 | 41 |
| | Credit aggregates | | 25 | 38 |
| | Factor analysis | | 44 | 42 |
| Bank Credit Analyst Financial Stress Index | | | 35 | 46 |
| Bordo, Dueker, and Wheelock (2000) Financial Stress Index | | | 64 | 15 |

Note: For those measures without explicit threshold values, plus-one standard deviation is used, as in Eichengreen, Rose, and Wyplosz (1996). Percentages are based on the number of months. Survey respondents identified 55 out of 276 months as stressful.

### Table 6: How Closely do the Subcomponents Match the Survey Results?

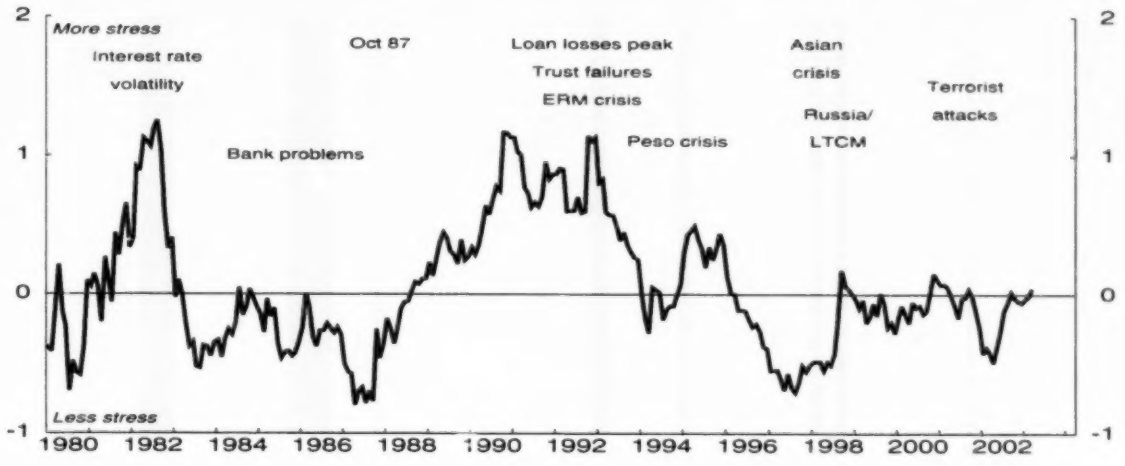
The Type I error is the probability that the measure fails to report a high-stress event (based on the survey results for the relevant market). The Type II error is the probability a high-stress event is falsely reported. Shading denotes the variable with the lowest Type I error.

| | | Type I error (%) | Type II error (%) |
|---|---|---|---|
| Measures of banking crises/stress | Demirgüç-Kunt and Detragiache (1998)<br>non-performing assets | 100 | 0 |
| | Hardy and Pazarbasioglu (1999)<br>deposits/GDP | 83 | 14 |
| | Hardy and Pazarbasioglu (1999)<br>lending/GDP | 100 | 3 |
| | Vila (2000)<br>deposit crashes | 80 | 8 |
| | Vila (2000)<br>bank share price crashes | 51 | 9 |
| | FSI standard<br>bank beta and bank spread | 51 | 14 |
| | FSI refined<br>beta > 1 and weak share performance and bank spread | 74 | 12 |
| | FSI GARCH<br>bank share price GARCH volatility | 66 | 20 |
| | Bank Credit Analyst<br>relative bank share prices (versus 2-year moving trend) | 100 | 21 |
| | Bordo, Dueker, and Wheelock (2000)<br>loan losses as a share of total assets | 83 | 2 |
| Measures of foreign exchange crises/stress | Eichengreen, Rose, and Wyplosz (1995, 1996)<br>nominal exchange rate, official reserves, interest rates | 82 | 6 |
| | Kaminsky and Reinhart (1996)<br>nominal exchange rate, official reserves | 88 | 0 |
| | FSI standard<br>Canadian dollar crashes weighted by volume traded | 35 | 15 |
| | FSI refined<br>Canadian dollar undervaluations | 65 | 28 |
| | FSI GARCH<br>Canadian dollar GARCH volatility | 35 | 33 |
| Measures of equity-market crises/stress | Vila (2000) and FSI standard<br>stock market crashes | 42 | 11 |
| | FSI refined<br>equity-risk premiums | 58 | 18 |
| | FSI GARCH<br>TSX GARCH volatility | 17 | 21 |
| | Bank Credit Analyst<br>real TSX new stock issuance | 92 | 20 |
| Measures of debt-market crises/stress | FSI standard<br>Bond yield spread, interest rate differential, bid-offer spread, CP-Tbill spread, yield curve | 15 | 9 |
| | FSI refined<br>Same as above, except bond yield spread is replaced by undervaluations | 35 | 12 |
| | Bank Credit Analyst<br>Private debt/GDP, market leverage, new bond issuance | 65 | 13 |
| | Bordo, Dueker, and Wheelock (2000)<br>Corporate bankruptcies, real interest rate, bond yield spread | 25 | 18 |

Note: Percentages are based on months. There were 276 months in the sample, of which: 35 months were classified as stressful for the banking sector (LDC, CCB, and Northland, 1992 loan losses); 17 as stressful for the foreign exchange market (oil-price collapse, pre-Plaza, ERM, peso, Asian, and Russian crises); 12 as stressful for the stock market (Oct. 87, Asian, and Russian crises, high-tech collapse, and 11 Sep.); and 20 as stressful for debt markets (LDC, late-92, peso, and Russian/LTCM crises).

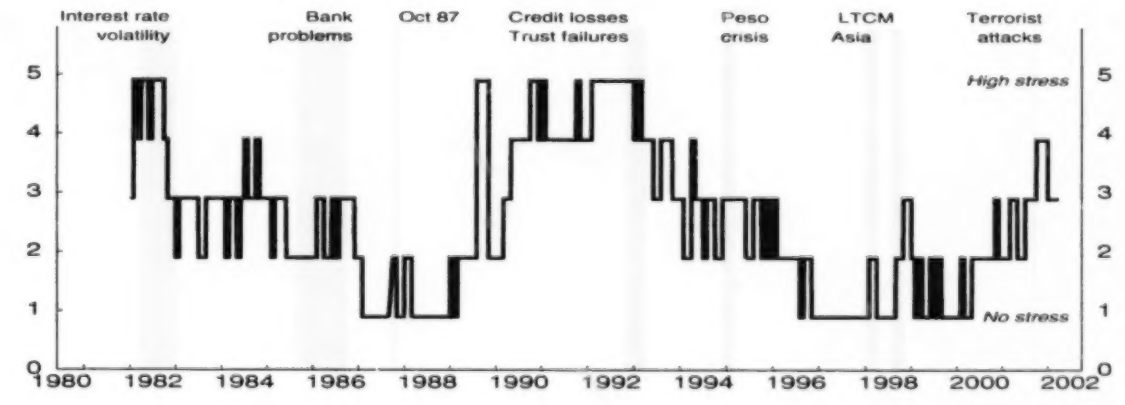
For those measures without explicit threshold values, +1 standard deviation is used, as in Eichengreen, Rose, and Wyplosz (1996). The BCA variables are trended to the best of the authors' knowledge in the same fashion as that employed by the BCA's U.S. index.

## Figure 1: Financial Stress Index
Bank Credit Analyst style for Canada




The actual BCA index uses U.S. data and their exact methods are not published.
Vertical shaded regions denote periods of high financial stress (according to survey responses in section 6).
Source: Authors' calculations based on McClellan (2001). Last value: Mar 03

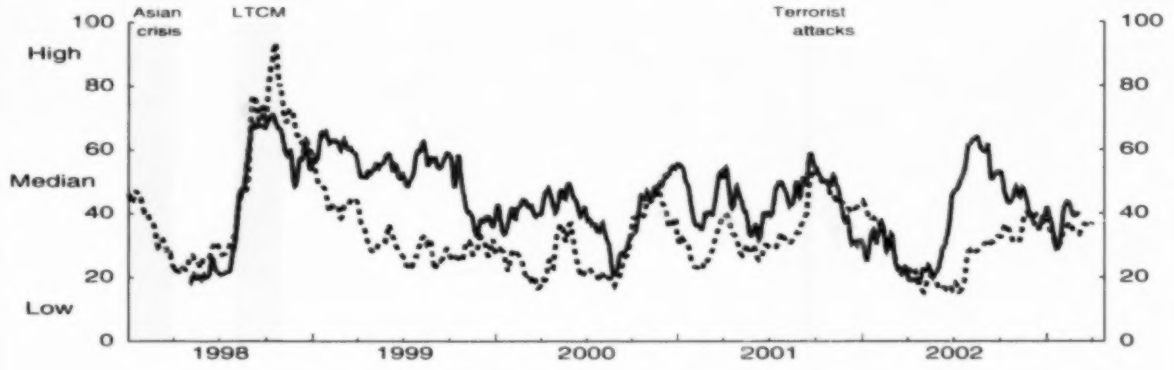
## Figure 2: Financial Stress Index
Bordo, Dueker, and Wheelock (2000) style for Canada




* The U.S. index is reproduced using Canadian data (loan losses, corporate bankruptcies, real interest rate, bond spreads).
Vertical shaded regions denote periods of high financial stress (according to survey responses in section 6).
Source: Authors' calculations. Last value: Mar 02

## Figure 3: Financial Stress

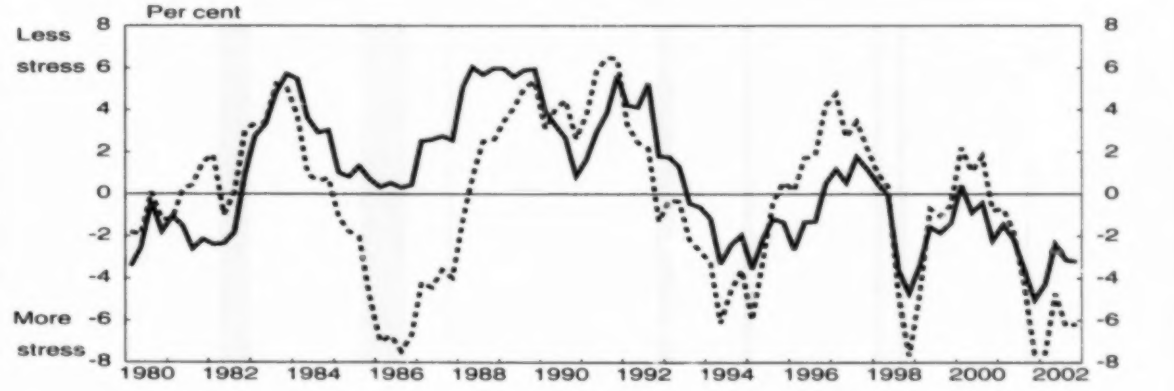
JP Morgan Liquidity, Credit & Volatility Index
Financial Stress Index




Source: Authors' calculations based on Kantor and Caglayan (2002).
Last value: 26 Mar 03

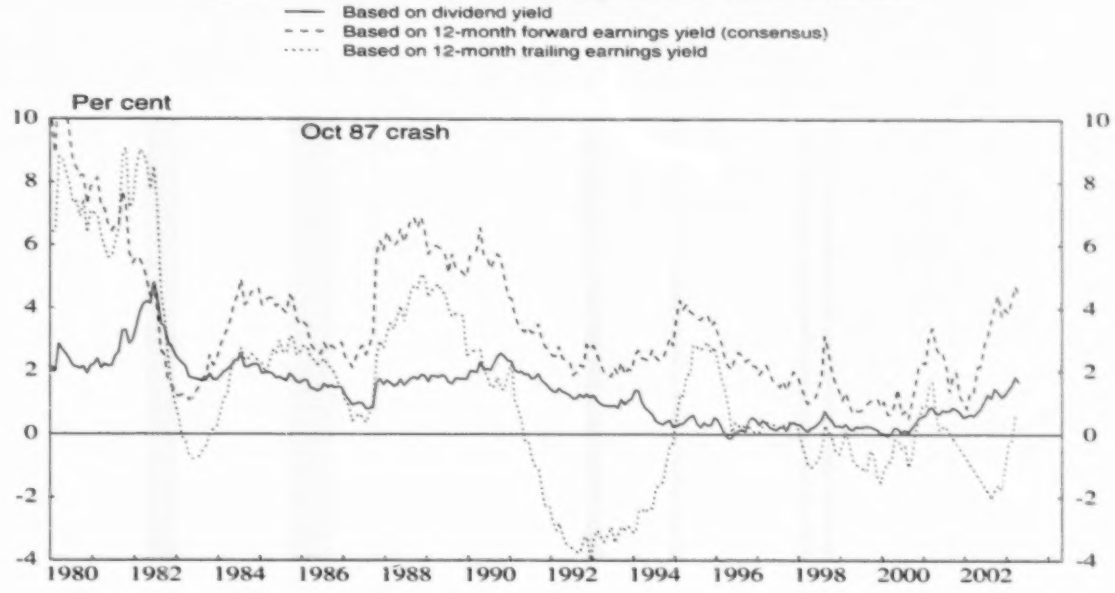
## Figure 4: Canadian-Dollar Deviations from Short-run Predicted Value

Fundamentals-based model* Hodrick-Prescott filter**




*Amano and van Norden (1995) and Djoudad and Tessier (2000), US$/Can$ exchange rate.
**Effective (C6) exchange rate.
Vertical shaded regions denote periods of financial market stress (according to survey responses in section 6).
Sources: Authors' calculations, Bank of Canada.
Last value: May 03

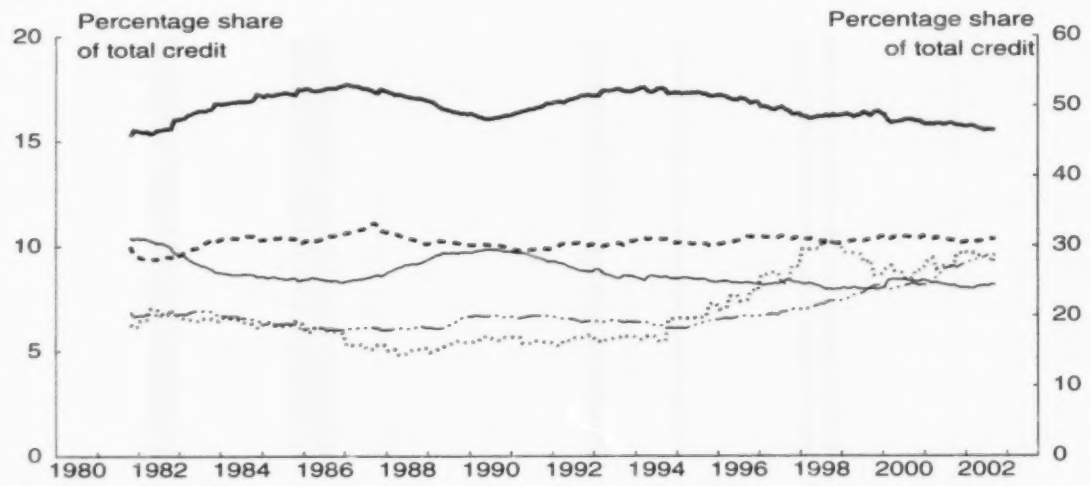
**Figure 5: S&P/TSX Composite Index Risk Premiums**




Vertical shaded regions denote periods of financial market stress (according to survey responses in section 6).
Sources: Authors' calculations, Bank of Canada, I/B/E/S. Last value: Apr 03

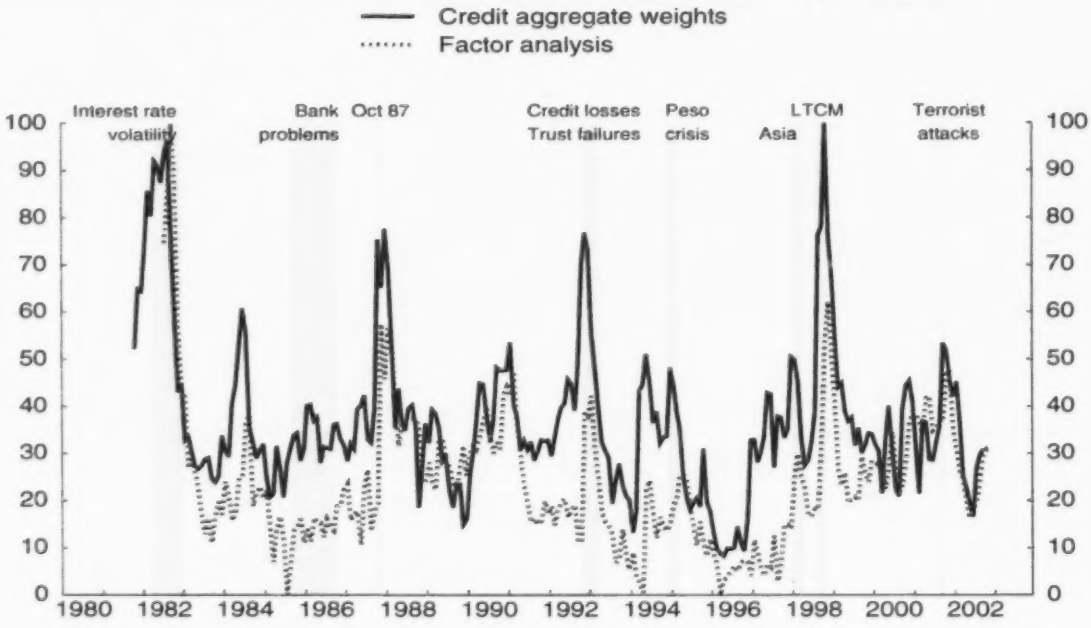
Figure 5 plots the equity-risk premium using the dividend yield discount method, and both trailing and forward earnings yields. Risk premiums rose steeply when the stock market crashed on 19 October 1987, and peaked shortly thereafter. Note that the measure using the trailing earnings yield is consistently lower than the one using expected forward earnings. This remains true even when one uses actual forward earnings, which suggests that consensus expectations are consistently overly optimistic.

## Figure 6: Canadian Credit Aggregates



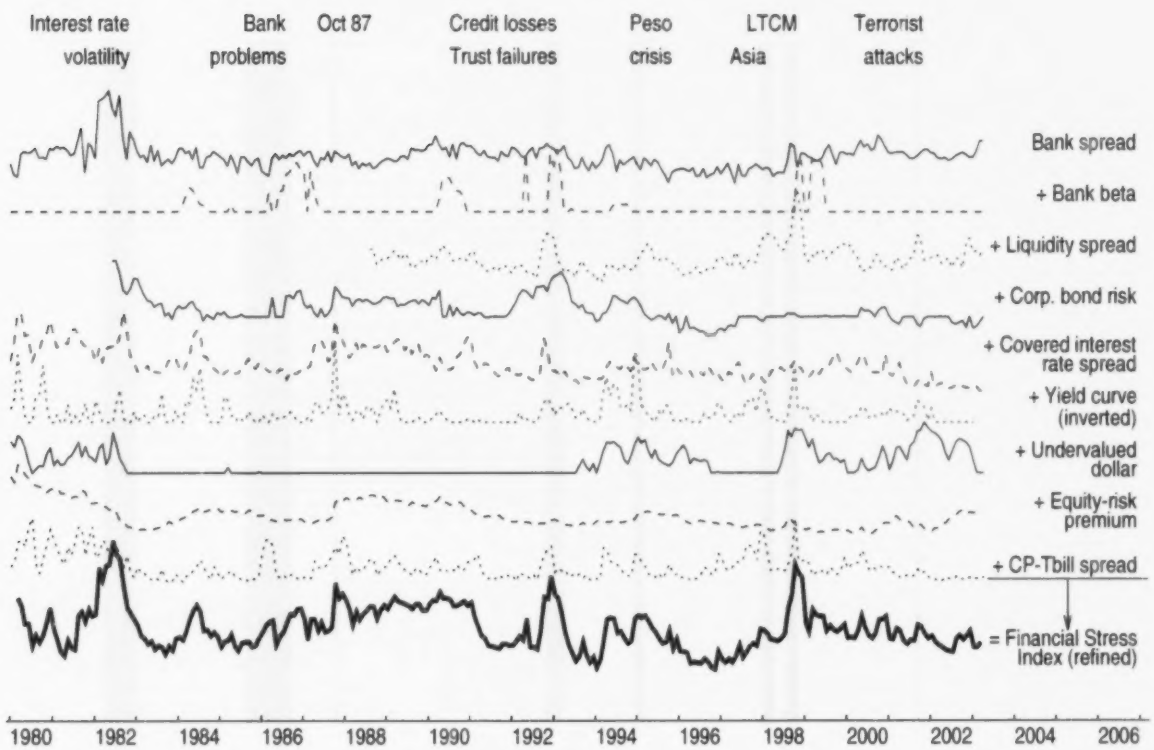

Vertical shaded regions denote periods of financial market stress (according to survey).
*U.S.-dollar-denominated bonds and loans to Canadian residents.
Sources: Authors' calculations, Bank of Canada, Statistics Canada. Last value: Sep 02

## Figure 7: Comparison of Weighting Techniques*




*The two techniques that produced the greatest difference in results.
Source: Authors' calculations. Last value: Mar 03

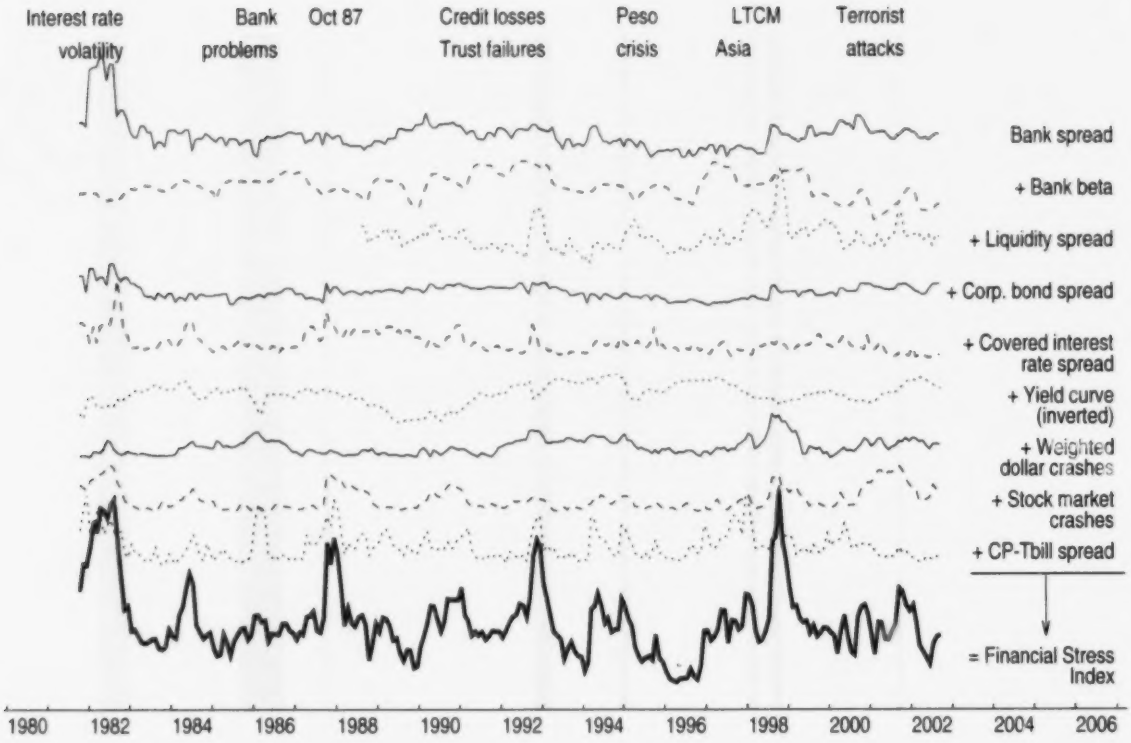
# Figure 8: Components of the Financial Stress Index
(refined variables, variance-equal weights)




Variables graphed proportionately to weight in index.
Source: Authors' calculations.

Last value: Mar 03

## Figure 9: Components of the Financial Stress Index
(standard variables, credit aggregate weights)




Variables graphed proportionately to weight in index.
Source: Authors' calculations.

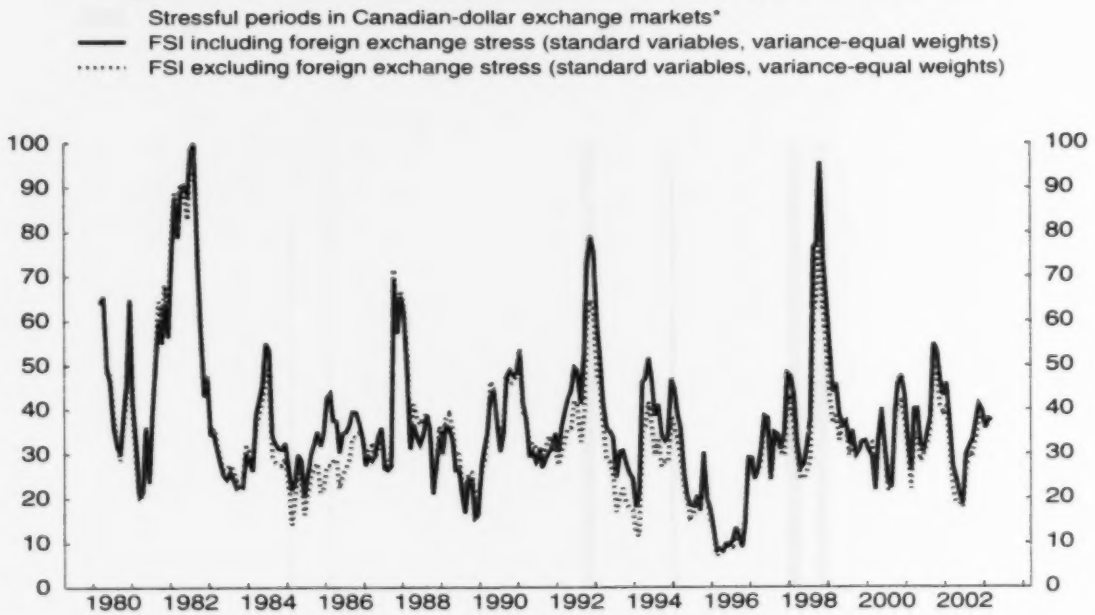
Last value: Mar 03

## Figure 10: Linkages Between Foreign Exchange Stress and Other Types of Financial Stress

*According to survey responses.
Source: Authors' calculations.

Last value: Feb 03

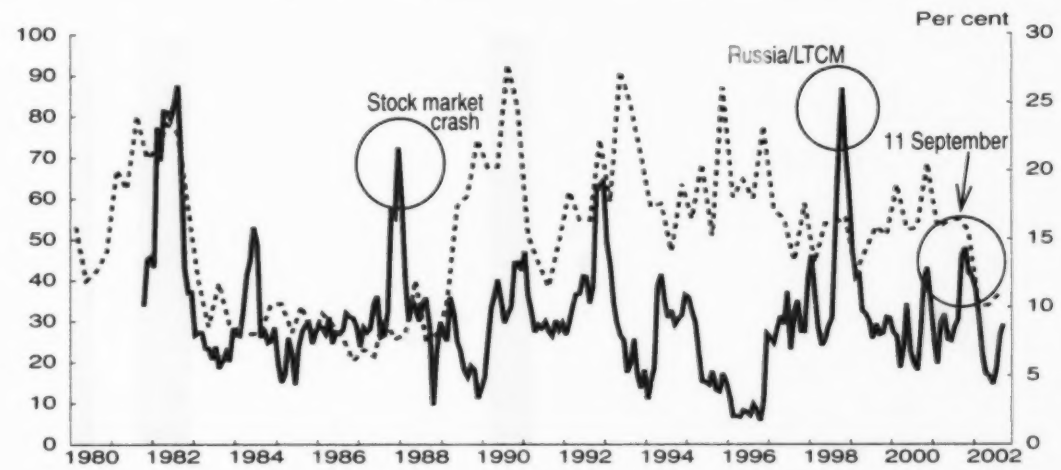
## Figure 11: FSI with and without Exchange Rate Stress




*According to survey responses.
Source: Authors' calculations.

Last value: Mar 03

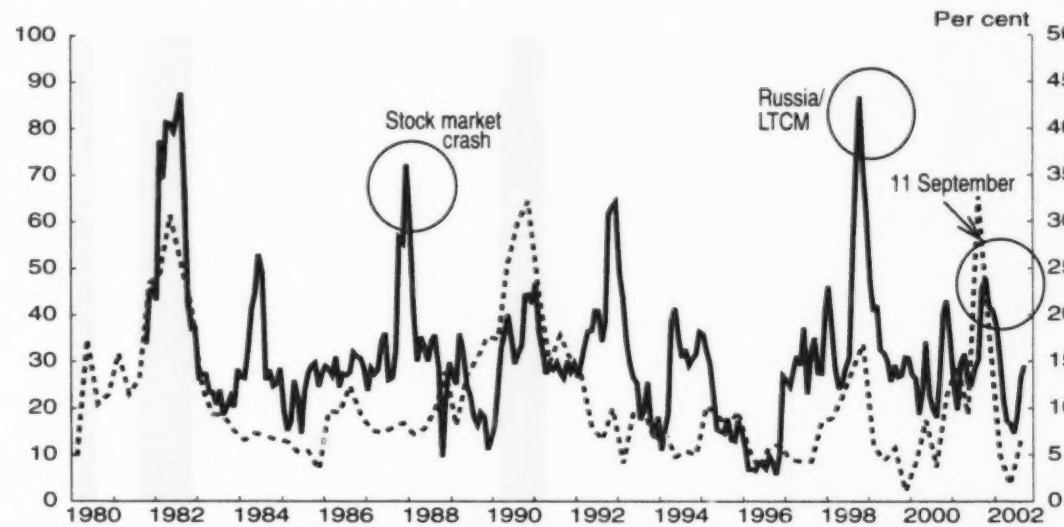
## Figure 12: Financial Stress and Consumer Confidence




Shaded regions denote Canadian recessions.
Sources: Authors' calculations, Conference Board of Canada.

Last value: Mar 03

## Figure 13: Financial Stress and Business Confidence




Shaded regions denote Canadian recessions.
Sources: Authors' calculations, Conference Board of Canada.

Last value: Mar 03

# Appendix A: Literature on Early Warning Indicators

The increasing incidence of financial crises in recent years has led to greater efforts to identify their causes and advance signals. Since the late 1990s, there has been an explosion of studies on EWI. Many of these studies focus on selecting and weighting indicators that are most useful in *predicting* crises. Hawkins and Klau (2000) find that these studies generally follow three approaches, as described below.

## A.1 Qualitative comparison

These studies graphically compare various indicators immediately preceding a financial crisis with those in normal times or in countries where there was no crisis. Examples include Caramazza, Ricci, and Salgado (2000), Eichengreen, Rose, and Wyplosz (1995), Eichengreen and Rose (1998), Frankel and Rose (1996), Glick and Moreno (1999), and the first part of Kaminsky and Reinhart (1999).

## A.2 Econometric modelling

This approach uses regressions to explain some measure of financial pressure (mostly exchange rate pressure), or logit or probit models to test whether indicators are associated with a higher probability of a financial crisis. Caramazza, Ricci, and Salgado (2000), Corsetti, Pesenti, and Roubini (1998), Demirgüç-Kunt and Detragiache (1998), Eichengreen and Rose (1998), Eichengreen, Rose, and Wyplosz (1995), Frankel and Rose (1996), Glick and Moreno (1999), Hardy and Pazarbasioglu (1999), Kruger, Osakwe, and Page (1998), Milesi-Ferritti and Razin (1998), Persaud (1998), Sachs, Tornell, and Velasco (1996), and Tornell (1999) use this approach.

## A.3 Non-parametric estimation

Studies that use this approach evaluate the usefulness of a number of different variables in signalling a pending or potential crisis. Threshold values are chosen for each indicator to strike a balance between the risk of many false signals and the risk of missing the crisis altogether (i.e., to minimize the noise-to-signal ratio). Often, indexes of fragility are subsequently constructed by counting the number of indicators that exceed their respective threshold values. Examples in this group of studies include Edison (2000), Goldstein, Kaminsky, and Reinhart (2000), Kaminsky, Lizondo, and Reinhart (1998), Kaminsky (1999), and the second part of Kaminsky and Reinhart (1999).

Most of these studies are done in a multi-country framework and typically focus on developing countries where financial crises occur more frequently. There is a limited literature on EWIs for

developed countries. The central banks of Sweden, Norway, and England have published financial stability indicators that cover conditions in the macroeconomy, financial markets, and financial institutions. The Bank of Canada has also been developing a package of such indicators, published as the *Financial System Review*. The IMF has been developing "macroprudential indicators" as part of a program to strengthen the international structure. To date, however, much of this effort involves the "qualitative comparison" approach. Few have created econometric models that formally test the explanatory and predictive abilities of the proposed indicators. Moreover, it is hard to identify conventionally defined "crises" in most developed countries. Thus there is relatively little qualitative information with which to test financial stability measures.

# Appendix B: Survey on Financial Stress

We are currently experimenting with methods of measuring financial stress. We would like to know how our measures of stress correspond to your view of historical events.

**Financial stress** is a gauge of the severity of disruptions to financial markets and institutions. Depending on their nature, situations of extreme stress are often referred to as crises, crashes, collapses, runs, or credit crunches.

We would like you to rank the following events in terms of how stressful they were for the **Canadian** financial system, where

- 1 = not stressful
- 2 = somewhat stressful
- 3 = very stressful
- DK = don't know

Please feel free to add comments in the margin.

**Date / Event / description**

- 1981 Canadian mortgage rates hit record high of 21.75%
- 1981 TSE 300 crashes by 18%
- 1982 **LDC debt crisis** Mexico, Brazil, Argentina, Hungary, Yugoslavia receive IMF interim bridge financing. Canada contributes $U.S. 250 million. IMF increases country quotas by 47.5% to cover mounting costs; international commercial banks are highly exposed to bad debts.
- 1982 Several small, mid-western US banks collapse and this leads to **bank runs** on Continental Illinois, Chase, and several other large US banks.
- 1984 US Fed and FDIC **rescue of Continental Illinois** ($US 10 billion) after failed acquisition initiates a large run on the bank.
- 1985 **Canadian small bank failures** Bank of Canada facilitates $255 million support package, as lender of last resort, to the Canadian Commercial Bank (CCB). Fearing contagion, Northland Bank asks for similar assistance.
- 1985 Emergency bank holiday in Ohio to stave off run on deposits
- 1985 First significant Savings and Loans failures in Maryland (not yet widespread)
- 1985 **Second LDC crisis** Canada contributes short-term bridge financing to Argentina, Mexico and Nigeria which cannot meet their debt obligations; Baker initiative coordinates debt rescheduling.
- 1985 **Plaza Accord** Before the Accord: the trade-weighted US dollar hits a record high. After the Accord: the US dollar falls by 10% in two weeks (US initiates coordinated devaluation with German and Japanese support)
- 1985 **CCB and Northland bankruptcies** (Bank of Canada has made combined advances of $Cdn. 1.8 billion). The bankruptcies have ripple effects: a number of other banks find it "impossible to retain sufficient deposits to fund their loans".
- 86-87 **Savings and Loans (S&L) crisis.** US Federal Savings and Loan Insurance Corporation (FSLIC) declared bankrupt
- 1987 Brazil declares debt service moratorium LDC borrowing rates soar
- 1987 **Louvre Accord** Before the Accord: the US dollar hits record low (50% off its peak in 1985). After the Accord: the US initiates coordinated intervention to support the dollar (lasts about 18 months)

- 1987 **"Black Friday"** - TSE crashes 17% in two trading days (parallels US crash)
- 1989 **"Grey Thursday"** - TSE 300 falls 3.5%
- 1990 US **junk bond market collapse**
- 1990 **Nikkei crash** Tokyo stock market falls by 50%
- 90-92 large loan losses at Canadian banks and trusts due to **real estate price collapse** (average residential house price falls $20,000, commercial property prices fall almost 40% over the next 6 years).
- 91-92 **Scandinavian banking crises**
- 1992 **ERM crisis** - European Exchange Rate Mechanism is effectively abandoned
- 1992 **Royal Trust distress** (taken over by Royal Bank in 1993)
- 1992 **Sovereign Life collapse** (Calgary-based)
- 1994 **Confederation Life collapse**
- 1994 **Global bond market reversal** - price volatility after shift in expectations
- 1995 **Mexican crisis** - Mexican bond spreads soar to almost 2500 basis points over US Treasuries
- 1997 **Asian financial crisis** begins with Thai Bhat devaluation and spreads to Malaysia, Indonesia, South Korea, the Philippines.
- 1998 **Russian/LTCM crisis** - Russia defaults on debt, emerging market bond spreads soar to 1700 basis points above US Treasuries. Long-Term Capital Management, a highly leveraged hedge fund, sustains massive losses. The NY Fed arranges a creditor bailout.
- 1999 **Brazilian currency crisis** - réal declines by over 40%
- 2000 High-tech **stock market bubble** bursts - Nasdaq falls by 40%, TSE falls by 19%
- 2001 **Turkish currency crisis** - lire falls 30% in one day
- 2001 **Argentinian financial problems** - Argentinian bond yields soar almost 2500 basis points above US Treasuries
- 2001 **Terrorist attacks** in the US

You may have noticed that descriptions of the above events did not explicitly mention Canadian dollar volatility and/or weakness.

- Do you feel that rapid exchange rate movements are stressful?
- Is there something inherently stressful about the Canadian dollar "hitting a new low"?
- Does raising interest rates to defend the dollar cause financial stress in other markets?

How would you characterize the degree of stress in Canadian currency markets during the following periods

| | |
|---|---|
| • November 1976 | dollar falls 7 cents from $1.03 |
| • January 1979 | dollar hits new low of 83.3 cents |
| • July 1984 | new low of 74.9 cents |
| • February 1985 | falls 4 cents |
| • | new low of 71.3 cents |
| • February 1986 | falls 2 cents (oil price crash) |
| • | new low of 69.5 cents |
| • January 1987 | dollar jumps 3 cents |
| • November 1991 | dollar peaks at 89.3 cents |
| • Aug-Sep 1992 | falls 4 cents (ERM spillover) |
| • January 1995 | falls 4 cents (Mexican crisis) |
| • October 1997 | falls 2 cents (Asian crisis) |
| • Aug-Sep 1998 | falls 3 cents (Russian crisis) |
| • | new low of 63.4 cents |
| • September 2001 | new low of 63.3 cents (US attacks) |

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